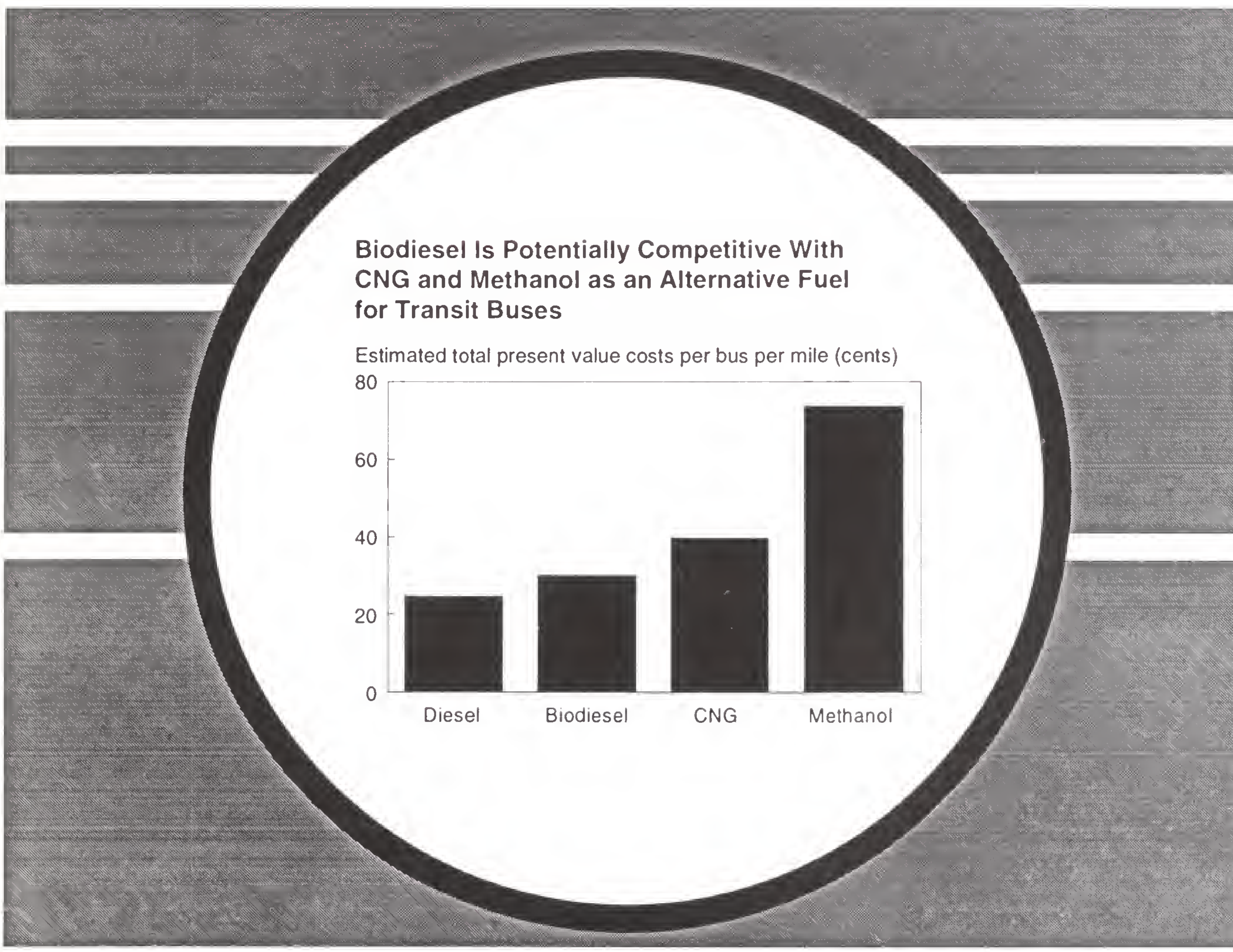
United States
Department of
Agriculture

Economic
Research
Service

IUS-5
September 1995

Industrial Uses Of Agricultural Materials

Situation and Outlook Report



Industrial Uses of Agricultural Materials Situation and Outlook. Commercial Agriculture Division, Economic Research Service, U.S. Department of Agriculture, September 1995, IUS-5.

Contents

Coordinator

Lewrene Glaser

Voice (202) 219-0091, Fax (202) 219-0035

Contributors

Ron Buckhalt, Alternative Agricultural Research and Commercialization Center
Wilda Martinez, Agricultural Research Service
James Duffield, Office of Energy and New Uses
Carmela Bailey, Cooperative State Research, Education, and Extension Service
Gloria Kulesa, U.S. Department of Energy
David Torgerson, ERS
Irshad Ahmed, Booz, Allen & Hamilton, Inc.
Charles Plummer, ERS
Allen Baker, ERS
John McClelland, Office of Energy and New Uses
Donald Van Dyne, University of Missouri
Anton Raneses, ERS
Alan Weber, National Biodiesel Board
Maryanne Normile, ERS
Edward Glade, Jr., ERS
Thomas Marcin, Forest Service
Nicolas Ahouissoussi, University of Georgia
Michael Wetzstein, University of Georgia

Statistical Support

Anton Raneses, (202) 219-0742   Charles Plummer, (202) 219-0717

Editor

Martha Evans

Graphics, Design, and Layout

Anne Pearl   Fannie Jolly   Joyce Bailey

Approved by the World Agricultural Outlook Board. Summary released September 26, 1995. The next summary of *Industrial Uses of Agricultural Materials Situation and Outlook Report* is scheduled for release on September 24, 1996.

Summaries and text may be accessed electronically. Call ERS Customer Service, (202) 219-0515, for details.

Acknowledgements

This report was made possible through the active support of many people and organizations. This issue was primarily funded by contributions from the U.S. Department of Energy's Office of Industrial Technologies and USDA's Alternative Agricultural Research and Commercialization Center. Donald Van Dyne, Professor of Economics at the University of Missouri; Irshad Ahmed, Director of Renewable Energy and Biotechnology at Booz, Allen & Hamilton, Inc.; and Harry Parker, Professor of Chemical Engineering at Texas Tech University; contributed time and expertise to this report.

Summary

Research and Market Demand Open New Opportunities for Agriculturally Based Industrial Materials

USDA's Alternative Agricultural Research and Commercialization Center has begun receiving royalty payments from two companies. The Center makes repayable investments in private firms to commercialize new industrial (nonfood, nonfeed) uses for agricultural and forestry materials and animal byproducts. Center funding was $6.5 million in fiscal 1995, and 10 projects are scheduled to receive funds.

USDA's Agricultural Research Service signed its 500th Cooperative Research and Development Agreement (CRADA). CRADA's allow joint collaboration between government scientists and industry to develop particular discoveries.

USDA's Cooperative State Research, Education, and Extension Service continues to work with the U.S. Department of Defense on the Advanced Materials from Renewable Resources Program. Coordinated by USDA's Office of Energy and New Uses, USDA and the U.S. Department of Energy (DOE) plan biomass demonstration projects for fiscal 1996. As part of its Alternative Feedstocks Program, DOE has signed agreements, including CRADA's, with private firms to develop polyols, a plastics monomer, and long-chain dicarboxylic acid monomers from renewable materials.

If biodiesel is approved as a certified technology for the Urban Bus Retrofit Rebuild Program, U.S. transit operations would be able to use it to meet air-quality regulations without any change in operability and maintenance. In the European Union, biodiesel production and commercial use expanded in 1994 and is expected to intensify in 1995.

A special article examines the expected costs of operating a transit bus fleet on three different alternative fuels—biodiesel, compressed natural gas (CNG), and methanol—with petroleum diesel as the base fuel. New fuel storage, delivery, and operating systems would be needed to use methanol or CNG, but no infrastructure changes or engine modifications would be necessary for biodiesel. Using a discounted present-value analysis, the total cost per bus per mile was estimated for the 30-year life of a transit fleet. Diesel buses had the lowest cost at 24.7 cents per mile. As biodiesel is blended with diesel, the cost per mile ranged from 27.9 to 47.5 cents, depending on the amount of biodiesel used and its estimated price. CNG's cost varied from 37.5 to 42 cents per mile, while methanol's cost was 73.6 cents per mile. This analysis indicates that, although biodiesel and biodiesel blends have higher total costs than diesel fuel, they have the potential to compete with CNG and methanol as fuels for urban transit buses.

The U.S. Gross Domestic Product (GDP) is expected to grow between 2.8 and 3.2 percent in 1995, down from 1994's increase of 4.1 percent. GDP growth for 1996 will range from 2.0 to 2.6 percent over 1995, with manufacturing output rising 2.6 to 3.0 percent during the year. Industrial markets for agricultural materials should grow somewhat slower than overall manufacturing for the next 6 quarters.

Industrial uses of corn are expected to total 780 million bushels in 1995/96, up 4 percent from the current forecast of 753 million for 1994/95. Most of the increase is expected to be in the production of fuel alcohol, up 4 percent, versus only a 2-percent rise in industrial starch. Ethanol sales in the reformulated gasoline market have been strong, despite the court-ordered elimination of the renewable oxygenate requirement. Several companies are manufacturing biobased polymers using starch, polyhydroxybutyrate/valerate, and polylactic acid. Cornstarch also is used to make xanthan gum, a popular ingredient in food, pharmaceuticals, and industrial products.

About 90 percent of collected cotton linters and motes are transformed by chemical or mechanical means into hundreds of diverse products, while only about 5 percent of cotton lint is used in industrial applications. In 1994, an estimated supply of 10.8 billion pounds of cotton lint, linters, motes, and textile wastes were available for industrial purposes.

Immunized dairy cows are producing antibodies that can be used to treat gastrointestinal tract infections. Transgenic goats and cattle are being developed to produce proteins—such as antithrombin III, human-serum albumin, alpha-1 proteinase inhibitor, and human lactoferrin—used in the treatment of infections and diseases. Dairy products also are used to produce low-cost, optically pure chiral intermediates for the pharmaceutical, food, and agricultural chemical industries.

The use of wood for energy is projected to reach between 2.8 and 3 quadrillion BTU's in 2000. The forest products industries themselves are the major users of wood for fuel, accounting for 71 percent of wood fuel consumed in 1992. Residential use, utilities, and other industries consume the remaining 29 percent. Production of liquid fuels from woody biomass is not economical at this time, but research is being conducted to lower costs.

Essential oils and their derivatives are widely used as flavors and fragrances, a market estimated to be worth $9 billion. In 1994, the United States exported essential oils valued at $176.1 million, while importing $206.7 million. U.S. production of peppermint and spearmint oils in 1994 were 7.4 and 2.2 million pounds, respectively. Supplies of orange oil and d-limonene, which are highly dependent upon orange juice production in Brazil and the United States, could continue to be tight into 1996.

USDA Works With DOE and DOD To Develop Biobased Materials

USDA's Alternative Agricultural Research and Commercialization Center has received royalty payments from two companies. USDA's Agricultural Research Service signed its 500th Cooperative Research and Development Agreement. USDA and the U.S. Department of Energy (DOE) plan biomass demonstration projects for fiscal 1996. USDA's Cooperative State Research, Education, and Extension Service continues to work with the U.S. Department of Defense on the Advanced Materials from Renewable Resources Program. As part of its Alternative Feedstocks Program, DOE has signed agreements with private firms to develop polyols, a plastics monomer, and long-chain dicarboxylic acid monomers from renewable materials.

AARC Center Begins Receiving Paybacks

USDA's Alternative Agricultural Research and Commercialization (AARC) Center has begun receiving royalty payments from two companies. The AARC Center makes repayable investments in private firms to commercialize new industrial (nonfood, nonfeed) uses for agricultural and forestry materials and animal byproducts. The Center requires at least a 50-percent match in funds and negotiates a payback arrangement for each project. Repayments are placed in a revolving fund to be reinvested with other firms.

The Leahy-Wolf Company of Franklin Park, Illinois, has made three royalty payments since March 1995. AARC Center funds were used to help Leahy-Wolf market a biodegradable release agent for concrete forms made from crambe or rapeseed oils for use in the construction industry. The company has established new distributors and is negotiating with a nationwide construction supply business to manufacture the product under license.

Natural Fibers Corporation of Ogallala, Nebraska, is the second firm to begin making royalty payments to the AARC Center. The company uses milkweed floss and goose down to make comforters and pillows. Sales are expected to reach over $1 million in 1995.

The AARC Center is governed by a nine-member Board of Directors, eight of whom represent producer, processing, financial, and scientific interests outside the Federal Government. Seven new members have been appointed since December 1994.

Funding for fiscal 1995 was $6.5 million. Ten projects are to receive funding this year. Some of the projects are:

- The Enbiomass Group, Inc., of Wilmington, North Carolina, is developing biodegradable foodservice packaging, with the functional characteristics of molded polystyrene, for use as plates, cups, and serving packages such as hamburger clamshells. The raw material is popcorn. Binders used in the process are also of agricultural origin—corn, potatoes, sugar, soybeans, and animal glue.

- Scientific Ag Industries of Atlanta, Georgia, is building a plant in Blakely, Georgia, adjacent to one of the world's largest peanut shelling operations, to produce high-grade activated carbon from pelletized peanut hulls. Activated carbon is used as filter material, removing contaminants from air and water.

- PhytoLife Sciences of Dublin, Ohio, is using proprietary electromembrane fractionation separation technology to isolate biologically active compounds from plants, flowers, seeds, aquatic plants, and algae in commercial volumes. The resulting valuable compounds can be used in pharmaceuticals, cosmetics, bioinsecticides, and fungicides.

- Environmental Composite Products, Inc., of Sullivan's Island, South Carolina, is planning to build a manufacturing plant near Barnwell and Aiken, South Carolina, to produce flooring for the intermodal transportation industry (dry containers for ocean freight, vans and flatbed trailers, and railroad cars) and cross arms for the utility industry. The raw materials used in the bonding process are various combinations of paper, paper sludge, nonrecyclable paper and other wood-processing residues. Veneers from underutilized tree species, such as yellow poplar and sweet gum, are also used. Currently, flooring is made from U.S. hardwoods and scarce tropical rain-forest hardwoods.

- Clean Green Polymers of Golden Valley, Minnesota, a wholly owned subsidiary of Environmental Technologies, USA, Inc., will blend 80 percent corn or wheat starch with recycled polymers to create a starch-plastic composite material. The material, which has the appearance and performance of standard plastics, will be injection molded to produce products such as disposable overcaps for bottles, plastic packaging for environmentally friendly products, and plastic parts for ammunition.

- Biorecycling Technologies, Inc. (BTI), of Fontanna, California, will be improving the groundwater around Chino, California, while converting agricultural waste into marketable products. Chino, which is about 50 miles east of Los Angeles, has what is probably the largest concentration

of dairy cows in the world, 300,000 head within a 10-mile radius. About 30 BTI plants will use cow manure to produce organic plant-growth media and potting soils, liquid organic fertilizers, and biogas, which will be used to produce heat or generate electricity.

- Stramit USA of Perryton, Texas, is using wheat and other cereal straws to manufacture insulated construction panels, primarily for nonload-bearing walls. The company is using machines and technology imported from Europe.

ARS Signs 500th Research Agreement With Industry

USDA's Agricultural Research Service (ARS) reached a technology-partnership milestone in fiscal 1995 with the signing of its 500th Cooperative Research and Development Agreement (CRADA). Authorized under the Technology Transfer Act of 1986, CRADA's allow joint collaboration between government scientists and industry to develop particular discoveries. The 500th CRADA, with Mycotech Corporation of Butte, Montana, enlists bioengineers and fermentation experts from ARS' National Center for Agricultural Utilization Research in Peoria, Illinois, to develop delivery systems incorporating a Mycotech-developed fungus for biological control of the sweetpotato whitefly, *Bemisia tobaci*. At the same time, the partnership is helping stimulate economic growth in rural America.

The agency's long standing record of developing new uses for starch and other carbohydrates continues. ARS scientists in Albany, California, entered into a CRADA with Mobil Chemical Company of Canadaigua, New York, for developing disposable starch-based products. ARS and Mobil are evaluating unique ways of processing starch to improve its adaptability to conventional plastic-processing equipment with the goal of producing low-cost, single-use items.

ARS scientists in Peoria, Illinois, have filed a patent application for the production of unique starch-encapsulated lipid spheres. The spheres have potential uses as fat substitutes, seed coatings, and protective coatings for young roots and shoots, as well as potential uses in wood adhesives and a great variety of other food and nonfood applications. In many instances, the spheres also can serve as vehicles for carrying active ingredients and other beneficial compounds.

In addition, ARS scientists at Wyndmoor, Pennsylvania, entered into a CRADA with Michigan Biotechnology Institute (MBI) of Lansing, Michigan, to develop specific end-use products from plasticized pectin/starch films first discovered and studied by ARS scientists. The films can be made in edible form and have potential in many food and nonfood applications. Under the CRADA, ARS and MBI researchers are working together to fabricate various articles from these films for evaluation.

Also in fiscal 1995, ARS filed a patent application on a method to process chicken feathers into fibers that can be used in a variety of ways, such as making paper-like products, textiles, filters, and seedling cups. This invention helps add value to a waste material from poultry processing that traditionally has been used in feed.

A patent has been issued to ARS for a process to manufacture nonallergenic rubber latex from domestic plant species such as guayule, milkweed, and goldenrod. Licensing negotiations are now underway. These nonallergenic rubber polymers have important applications in the production of products that come in contact with human skin, such as the rubber gloves used by medical professionals.

ARS scientists and engineers in Beltsville, Maryland, are collaborating with companies in several industries to convert urban and industrial wastes into useful products, such as soil amendments and wallboard. The objective is to eliminate these waste materials from landfills and other disposal sites and turn them to productive use.

Partnerships with industry were not the only alliances formed in fiscal 1995. ARS led a team of USDA agencies in negotiating a formal agreement with the U.S. Department of Energy (DOE) on new and creative measures to solve agricultural problems using the combined talents and scientific disciplines of both departments. The USDA agencies involved include the Agricultural Marketing Service; Animal and Plant Health Inspection Service; Cooperative State Research, Education, and Extension Service (CSREES); Food Safety and Inspection Service; Forest Service; and Natural Resources Conservation Service. USDA Secretary Dan Glickman and DOE Secretary Hazel O'Leary are scheduled to sign a Memorandum of Understanding with the goal of facilitating cooperative technology, research, development, transfer, utilization, and commercialization efforts.

To further enhance technology transfer, ARS' Office of Technology Transfer and the State of Florida began working as partners in fiscal 1995 to develop an infrastructure to support economic development that would benefit, not only Florida's companies, but its farmers as well. Florida's network of 67 county-wide economic development field offices will provide ARS with enhanced information and access to the State's industries. Similar partnerships are being forged with 17 other States.

OENU Involved in Joint Energy Projects

USDA, in an effort coordinated by the Office of Energy and New Uses (OENU), will help DOE launch a series of biomass demonstration projects beginning in fiscal 1996. USDA participated as a full partner in designing the Request for Proposals (RFP), entitled Biomass Power for Rural Development, and will participate in awarding project funding. Over 350 groups have requested the RFP. DOE's funding for the selected projects is anticipated to be $80 million over a 6-year period with up to five awards expected. USDA indicated a willingness to leverage DOE's funds with existing USDA programs and authorities where appropriate. A panel was held to determine leading candidates. Final announcement of winners is awaiting clarification of DOE's 1996 budget.

Workshops were held in Vermont, Minnesota, and Alabama to offer and receive comments on biomass energy. Follow-up

meetings were held in California, Missouri, and Florida. These forums took place in areas likely to apply for funding. USDA experts, led by OENU, discussed how existing USDA authorities could be used in the context of the forthcoming RFP. The response from utilities, farm groups, and environmentalists was very favorable.

Based on an economic analysis OENU conducted with the White House, DOE, and the U.S. Environmental Protection Agency (EPA), production of liquid fuel and electricity from biomass is possible in several areas of the country. If technology development and feedstock yield improvements are successful, biomass energy could provide farmers with new market opportunities and rural America with a new industrial base.

OENU teamed up with DOE's Biofuels Systems Division to conduct a life-cycle study of biodiesel production in the United States. The main purpose of the study is to produce an analytical framework for evaluating energy use, environmental effects, and input costs of biodiesel production in the United States on a life-cycle basis. Life-cycle analysis evaluates a product or activity through all of its stages—from raw material access through manufacturing to consumer use and waste management (recycling or disposal). This concept is often referred to as a cradle-to-grave assessment.

The study will require detailed data on farm production, extraction and processing of raw materials, manufacturing, transportation, and distribution. An industry/government working group—including USDA, DOE, EPA, Ecobalance, Inc., and the National Biodiesel Board—was established to collect data, develop assumptions, create scenarios, and define boundary conditions for the life-cycle analysis. This study also includes a parallel effort to develop a life-cycle model for petroleum diesel. The two models will be used to compare net energy use, environmental effects, and life-cycle costs of petroleum diesel versus biodiesel.

CSREES Continues Collaborations with DOD

In 1991, the U.S. Department of Defense (DOD) began working with CSREES on a program to develop biodegradable polymers. DOD interest stemmed from the 1987 Marpol Treaty, which stipulated that, beginning in 1995, ocean dumping of plastic is prohibited unless it is marine degradable. This research expanded on a decade-old alliance to develop a domestic source of natural rubber for aircraft and land-based-vehicle tires. Three years of funding yielded a new generation of degradable polymers with functionality that mimics petroleum-based plastics. However, their purchase price is two to three times higher than petroleum-based products.

In 1993, DOD began exploring the possibility of moving beyond rubber and starch polymers to a full range of industrial products made from plant and animal materials. The Advanced Materials from Renewable Resources (AMRR) program was established to focus on applied research, development, and precommercial work in seven areas: engineering nylons, biodiesel fuel, functional fluids, oil-selective adsorbents, flexible paints and coatings, natural biocides and biocidal coatings, and vegetable-oil epoxides. This program opened a broad interaction between USDA and DOD. For example, CSREES is working with the U.S. Army Tank Automotive Command's Technical Insertion Program, which will test agriculturally based industrial products for military acceptability.

A number of products developed or improved under the AMRR Program are undergoing testing; for example:

- The Mobility Technology Center at Fort Belvoir, Virginia, is evaluating environmentally acceptable hydraulic fluids, most of which are based on vegetable oils. Laboratory testing should be completed in fiscal 1996. Field testing in fiscal 1997 and revision of military specifications will allow military procurement of these products.

- Fort Belvoir also is evaluating potential replacements for P-D-680 solvents, which are used for dry cleaning and degreasing. Many candidates are based on renewable resources such as terpenes, limonene, and vegetable-oil methyl esters. Revised specifications are expected by the end of fiscal 1996.

- An evaluation of biodiesel by the Tank Automotive Research, Development, and Engineering Center (TARDEC) in Warren, Michigan, at the Army's proving ground in Yuma, Arizona, has been completed. When mixed as a 20-percent blend with JP-8 fuel, biodiesel reduced emissions and improved acceleration in five types of trucks. Other tests have shown that biodiesel serves as a lubricant when blended with low-sulfur diesel. Laboratory testing at Fort Belvoir is ongoing.

- The University of Arizona has signed a nonexclusive agreement with Merck and Company to test a guayule-resin fraction for activity against a pathogenic fungus.

- Field studies, conducted at Virginia State University to evaluate glucosinolates in rapeseed meal as a pesticide for black rot in peanuts, show that best results were achieved when the meal was used as an extender for the conventional pesticide, thereby, reducing the amount of chemical required and enhancing its efficacy.

- Through TARDEC, Wright-Patterson Air Force base is testing urethane-type packaging foam made from lesquerella oil. The foam, developed at the University of Southern Mississippi, showed excellent shock absorbing properties.

- Through TARDEC, the Army is testing a guayule, epoxy-amine, peelable coating on metal panels at Cape Kennedy, Florida, for corrosion protection during exposure to fog and salt. The coating was developed at the University of Southern Mississippi.

- TARDEC testing of guayule-rubber truck tires at the Yuma Proving Ground is expected to be completed this fall. Results thus far show guayule tires to be comparable to tires made from hevea rubber.

In July 1995, a USDA team headed by CSREES held discus-

sions with officials at the U.S. Army Environmental Center (AEC) in Edgewood, Maryland, to explore scientific collaboration in industrial products, remediation of contaminated soils, and other areas. AEC is a technology testing and demonstration center that specializes in heavy metals, ground water quality, unexploded ordnance, and numerous other environmental problems. During the discussions, the USDA team was looking for possible applications of agricultural technology to solve defense mission needs and for applications of defense technology to solve agricultural mission needs.

DOE's Alternative Feedstocks Program Is a Collaborative Effort

The Alternative Feedstocks Program, administered by DOE's Office of Industrial Technologies, is comprised of various industrial partners and five DOE laboratories: Argonne National Laboratory (ANL), Idaho National Engineering Laboratory (INEL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest Laboratories (PNL). The program's mission is to promote cost-effective utilization of renewable biomass resources as feedstocks in the manufacture of high-volume chemicals and high-value products through cost sharing of research.

Within the last 9 months, the program has achieved significant growth. Some recent projects include:

- PNL is in the last year of a 3-year CRADA with International Polyol Chemicals, Inc. (IPCI), a small business located in Redmond, Washington. The goal is to complete sufficient process development to allow commercialization of IPCI's process for production of polyols—propylene glycol, ethylene glycol, and other diols—from glucose. PNL is providing expertise in selective catalytic processing. USDA's AARC Center also is involved with the project.

- ANL, NREL, ORNL, and PNL continue their joint research and development project, with assistance from MBI, to demonstrate the feasibility of producing succinic acid from cornstarch. The succinic acid could then be used as a feedstock for manufacture of commodity plastics, synthetic fibers, food additives, and solvents for paints and paint removers. The consortium is currently evaluating several opportunities to collaborate with private industry.

- In July 1995, INEL entered a CRADA with General Electric (GE) to explore opportunities to develop an alternate method of producing a plastics monomer. GE is a world class developer, producer, and marketer of engineering thermoplastics. INEL has expertise in engineering, selecting, and optimizing microorganisms to maximize chemical activity. Together, this team hopes to commercialize a novel approach to polymer production, based on renewable feedstocks.

- Recently, DOE entered into a cooperative agreement with GE for biosynthesis of long-chain dicarboxylic acid monomers from renewable feedstocks. GE will use molecular biology techniques to construct gene banks and select genes needed to produce an improved biocatalyst. Bioprocess development also will be performed to identify substrates, optimize bioprocess conversion conditions, screen product separation technologies, and determine overall process economics. In developing applications, GE will determine the suitability of monomers prepared from different substrates for the preparation of target polymers and characterize the resulting polymer properties.

- NREL's clean fractionation process has attracted a major industrial partner who is interested in cellulosic material applications. A formal signing of a CRADA is expected in the near future. This project will focus on the separation of woody biomass into separate fractions—lignin, cellulose, and hemicellulose—with little or no cross contamination. The fractions can then serve as starting materials for chemicals production. Potential products include a wide range of cellulose-based materials, such as rayon and acetate fibers, thermoplastics, laminates and films, coatings, and additives to paint and drilling muds.

- NREL is nearing a formal CRADA with a state agency, a small business, and a university to develop biobased levulinic acid. The industrial partner will build a 1-ton-per-day pilot plant to convert paper mill sludge into levulinic acid. The consortium, lead by the New York State Energy Resources Development Authority, will explore opportunities to improve and commercialize the conversion of the levulinic acid into commodity and specialty chemicals, such as fuel and polymer additives and agrochemicals. [Ron Buckhalt (AARC Center), (202) 690-1633; Wilda Martinez (ARS), (301) 504-6275; James Duffield (OENU), (202) 501-6255; Carmela Bailey (CSREES), (202) 401-4640; and Gloria Kulesa (DOE), (202) 586-8091]

Modest U.S. Economic Growth Expected in 1995 and 1996

The U.S. Gross Domestic Product (GDP) is expected to grow between 2.8 and 3.2 percent in 1995, down from 1994's increase of 4.1 percent. GDP growth for 1996 will range from 2.0 to 2.6 percent over 1995, with manufacturing output rising 2.6 to 3.0 percent during the year. Industrial markets for agricultural materials should grow somewhat more slowly than overall manufacturing for the next 6 quarters.

The U.S. Gross Domestic Product (GDP) grew 4.1 percent from the fourth quarter of 1993 to the fourth quarter of 1994. The robust growth benefitted goods relative to services and durables relative to nondurables. Of nine major industries using agricultural materials (lumber and products, furniture and fixtures, industrial machinery and equipment, transportation equipment, textile-mill products, paper and products, chemicals and products, rubber and plastic products, and leather and products), six expanded output faster than GDP. Industrial machinery and equipment led the way with 13.2 percent growth. Rubber and plastic products had a 10.1-percent rise in output, as real (adjusted for inflation) sales in automobiles and auto parts and business equipment grew 6 and 18 percent, respectively. Real spending on housing and consumer durables increased more than 8 percent. As a result, manufacturing prospered, with lumber and textile mill production up sharply. Only leather product output declined in 1994, by 1.5 percent.

Strong growth in employment, real income, and industrial output worked together in 1994 to overcome the negative effects of increasing short- and long-term interest rates, declining government spending, and an increasing trade deficit. The economy expanded so rapidly that capacity utilization in December 1994 reached 85.5 percent, well above the rate historically associated with rising inflation. Yet, by any measure, inflation was below 3 percent.

Manufacturing Output Declines in the Second Quarter

To prevent higher inflation, the Federal Reserve Board (Fed) raised short-term interest rates six times from February 1994 to February 1995. The resulting slowdown in the U.S. economy in 1995 was most pronounced in the second quarter. In the first quarter of 1995, GDP grew 2.7 percent, likely buoyed by an almost 150 basis-point drop in long-term interest rates. In the second quarter, GDP rose only 1.1 percent and inventory accumulation declined sharply, which in turn hit the industrial sectors of the economy particularly hard. From automobiles to building materials, factory output was cut. Industries using agricultural materials saw their production decline more than the 3.4-percent fall in overall manufacturing output (table 1). Lumber-and-products and furniture-and-fixtures output dropped 13.4 and 10.3 percent, respectively, reflecting a sharp drop in the demand for housing and home furnishings. Transportation equipment output decreased 15.0 percent in the second quarter, reflecting a decline in car and light truck sales and lower inventories.

Table 1--Growth rates for GDP, industrial production, and selected industries using agricultural materials

Item	4th qtr 1994	1st qtr 1995	2nd qtr 1995
	Percent change		
Gross domestic product	5.1	2.7	1.1
Industrial production	5.9	5.2	-2.4
Manufacturing	7.7	5.1	-3.4
Lumber and products	5.0	-1.3	-13.4
Furniture and fixtures	0.8	3.2	-10.3
Industrial machinery and equipment 1/	12.5	9.9	4.2
Transportation equipment	9.5	9.4	-15.0
Textile-mill production	10.3	0.8	-12.6
Paper and products	7.5	-1.2	-2.2
Chemicals and products	5.4	12.4	-6.0
Rubber and plastic products	11.6	4.6	-6.5
Leather and products	-4.1	-9.2	-13.9

1/ Overall sector growth. Computers and office equipment grew 25.5, 27.3, and 31.0 percent, respectively. Growth in other industrial machinery and equipment categories was much lower.

Sources: Gross Domestic Product Release, Department of Commerce, Bureau of Economic Analysis, August 1995; and Industrial Production Report, Federal Reserve Bank, Washington, DC, September 1995.

The chance of higher inflation abated in the second quarter of 1995 due to the declines in employment and industrial production and the sharp decrease in capacity utilization to 83.3 percent in June 1995. As a result, the Fed lowered the Federal funds rate (the rate at which banks borrowed from each other to meet reserve requirements) by 0.25 percent in July 1995. The bank prime rate went from 9.0 percent to 8.75 percent.

Growth Should Rebound in the Rest of 1995 and 1996

Lower interest rates, slowing retail and manufacturing inventory accumulations, and good consumer and business balance sheets suggest 2.0- to 2.6-percent annualized growth in the last 2 quarters of 1995. In an environment of continued low interest rates, housing and plant spending will ordinarily pick up. Car sales will increase some, but much of the replacement demand was satisfied in 1994. The boom in business-equipment spending should continue, but at a slower pace than in the first 8 months of 1995.

August's preliminary industrial production estimate was up 1.1 percent on top of July's 0.3-percent increase, which was largely due to high electricity usage during the month's unusually hot weather. Manufacturing was flat during July. August showed a dramatic upturn with manufacturing up 1.0 percent. Except for paper and products, which was constrained by the highest capacity utilization rate in the economy, every major industrial user of agricultural materials took part in the growth. Because of sales incentives, automobile and light truck output, the largest component of transportation equipment, rose 6.0 percent in August. Other sectors showed less dramatic turnarounds. August's pace of industrial recovery, while not sustainable because of large inventories, is evidence of an overall pickup in manufacturing.

Nonetheless, the sectoral pattern and modest level of growth for the rest of 1995 yield a mixed outlook for industries using agricultural materials. Housing and housing-related durable spending should grow moderately, as excess housing and durable inventories decline. This in turn will stimulate output in lumber and products, furniture, and textile-mill products in the third and fourth quarters. The small growth expected in domestic car sales, aided by a weak dollar, should modestly boost output of transportation equipment. The continued drawing down of excess inventories will keep growth and inflation modest. GDP is expected to grow between 2.8 and 3.2 percent in 1995.

The annual growth rate for 1996 over 1995 is expected to be between 2.0 and 2.6 percent. Interest rates should fall slightly below current levels. A weak but appreciating dollar and stronger growth in Europe, Japan, and Mexico will lead to strong export gains in 1996. Moderate construction growth will be supported by low interest rates and a modest 3.5-percent inflation rate. Export and construction growth should increase manufacturing output 2.6 to 3.0 percent. Lumber and furniture output is expected to rise more than 3 percent in 1996.

Moderate Growth Seen in Crude Oil Pricing

Despite a runup in the price of crude oil starting in early 1995—the refiner's acquisition cost was close to $19 per barrel during May—oil prices are likely to move down in the second half of 1995. Slow growth rates in developed countries will keep crude oil prices down. The second quarter of 1995 saw an average crude oil price of $18.20 per barrel, which will fall to about $16.75 in the third quarter because of a very slow recovery in world industrial production. The U.S. Department of Energy's Energy Information Administration (EIA) expects oil prices to average about $17.60 per barrel for the last quarter of 1995 and all of 1996.

Gasoline prices are expected to average $1.21 per gallon in 1995, up from $1.17 in 1994. The price is expected to hit $1.25 per gallon in 1996. Because of weak industrial production, diesel prices in 1995 probably will go up only 2 cents above 1994's $1.11 per gallon. Reflecting a moderate improvement in industrial output, diesel prices are expected to be up 5 cents per gallon in 1996.

Some analysts, who expect some stronger U.S. and world growth, expect crude oil prices to average about $18.50 per barrel for the last quarter of 1995 and all of 1996. Gasoline and diesel prices would then be about 3 cents higher than those expected by EIA in 1996. In either case, real crude and product prices are expected to be quite low for the near term. [David Torgerson, (202) 501-8447]

Ethanol, Biopolymers, and Xanthan Gum Use Corn As a Feedstock

Industrial uses of corn are expected to total 780 million bushels in 1995/96, up 4 percent from 1994/95. Ethanol sales in the reformulated gasoline market have been strong, despite the court-ordered elimination of the renewable oxygenate requirement. Several companies are manufacturing biobased polymers using polyhydroxybutyrate/ valerate, starch, and polylactic acid. Cornstarch also is used to make xanthan gum, a popular ingredient in food, pharmaceuticals, and industrial products.

Industrial uses of corn are expected to total 780 million bushels in 1995/96, up 4 percent from the current forecast of 753 million for 1994/95 (table 2). Most of the increase is expected to be in the production of fuel alcohol, up 4 percent, versus only a 2-percent rise in industrial starch. In 1995/96, industrial uses are expected to account for 9 percent of total corn use, up from 8 percent in 1994/95.

Industrial use of starch tends to follow the economy. Thus, the slower economic growth expected in 1995/96 will likely slow starch use. In 1994/95, industrial starch is expected to account for 213 million bushels of corn, up 3 percent from 1993/94. The expanding economy late in 1994 and early 1995 helped increase starch use. However, the recent slowdown in economic growth will likely hold corn use for industrial starch to a 2-percent rise over the year before.

Preliminary prices for cornstarch, f.o.b. Midwest, are expected to average $12.18 per hundredweight (cwt) in 1994/95, down from $12.61 in 1993/94. Producers appear to be able to pass along higher raw material costs, because when corn prices rise, so do starch prices. For example, cash corn prices in central Illinois went up 9 cents from April to May 1995 and starch prices increased 24 cents per cwt. By August, starch prices had climbed another $1.20 to $13.85 per cwt, while corn prices were up 18 cents per bushel. As starch prices increase, industrial users are likely to begin searching for lower cost alternatives and, to the extent possible, shift away from starch.

The expected increase in production of fuel ethanol in 1995/96 is tied to the announced expansion of plants in Minnesota and Nebraska. These States have provided incentives to encourage the production of alcohol. On the other hand, current high prices for corn have made dry-milled alcohol production less profitable than in the past. Two companies announced they are stopping production at two plants, one in Ohio and one in North Dakota, where the State legislatures have limited funding for ethanol subsidies. In 1994/95, corn used to make fuel alcohol is expected to increase 18 percent from 1993/94, as the industry expanded to meet demands for oxygenates for reformulated gasolines and the winter oxygenated program.

Ethanol Use Up Despite Court Ruling

The reformulated gasoline program began on January 1, 1995, as mandated by the Clean Air Act Amendments of 1990. The program's renewable oxygenate requirement (ROR) was held up by a stay issued by the U.S. District Court of Appeals for the District of Columbia on September 13, 1994. The Court reversed the ROR in a unanimous decision by a three judge panel in early June 1995. The Administration immediately appealed the decision to the full Court, but that appeal was rejected at the end of July. The Administration is considering a final appeal to the U.S. Supreme Court. (For more information on the ROR and the court case, see the December 1994 issue of this report.)

Despite these unfavorable Court rulings, ethanol sales in the reformulated gasoline market have been strong. In the Chicago and Milwaukee markets, ethanol's market share was as high as 70 percent. Ethanol also fared well in the winter oxygenated fuel markets, capturing virtually 100 percent of the market in the Colorado front range, and maintaining sig-

Table 2--Industrial and food uses of corn, 1990/91-1995/96

Marketing year 1/	HFCS 2/	Glucose and dextrose 2/	Cereals and other products	Starch: Food uses	Starch: Industrial uses	Starch: Total 3/	Alcohol: Beverage	Alcohol: Fuel	Total industrial use 4/
					Million bushels				
1990/91	379	200	114	35	197	232	80	349	546
1991/92	392	210	116	36	202	237	81	398	600
1992/93	414	215	117	36	202	238	83	426	628
1993/94	442	223	118	37	207	244	83	458	665
1994/95 5/	460	230	118	38	213	250	84	540	753
1995/96 6/	475	235	118	38	217	255	84	563	780

1/ Marketing year begins September 1. 2/ High fructose corn syrup (HFCS), glucose, and dextrose are primarily used in edible applications, such as food and health-care products. 3/ Industry estimates allocate 85 percent of total starch use to industrial applications and 15 percent to food applications. 4/ Industrial uses of starch and fuel alcohol. 5/ Preliminary. 6/ Forecast.

nificant market share in other oxygenated fuel markets. On the other hand, ethanol has not gained significant market share in the Northeast reformulated gasoline market due to heavy competition from methyl tertiary butyl ether.

While ethanol's market share in conventional gasoline, oxygenated fuel, and reformulated gasoline have grown, ethanol is used primarily in the Midwest. Many analysts believe the costs of using ethanol in other markets, particularly the reformulated gasoline markets of the Northeast and California, is uncompetitive because of transportation and other distribution logistics. A possible solution is converting ethanol into ethyl tertiary butyl ether (ETBE) or other ethers at the refinery, blending ETBE with gasoline, and shipping the finished reformulated gasoline to market in common carrier pipelines.

On August 4, 1995, the Internal Revenue Service announced a new regulation that allows ETBE access to the excise tax exemption for ethanol blenders. The rule also allows refiners to claim the tax credit at the refinery, which means they no longer have to keep fuels that qualify for the tax exemption separate from other fuels in the pipeline and at the terminal. If this rule is effective in reducing the costs of using ethanol in reformulated gasoline, significant quantities of ETBE-blended fuels could be sold in the Northeast and California within the next year.

Biodegradable Polymer Technologies Continue To Improve

As environmental concerns regarding waste management continue to mount, biodegradable polymers could become an increasingly important piece of the waste management puzzle. The three main types of biobased-polymers—made using starch, polyhydroxybutyrate/valerate (PHB/V), and polylactic acid (PLA)—fit the "cradle to grave" design concept, which calls for the material to be recyclable and/or degradable.

Several companies claim to have developed 100 percent biodegradable resins using starch or starch-derived compounds in combination with other biodegradable additives and naturally occurring minerals. However, full biodegradability can occur only when these materials are disposed of properly in a biologically active environment, such as municipal composting or sewage treatment facilities. (For more information on biodegradability, see the special article on biopolymers in the June 1993 issue of this report.) In addition, not all claims of biodegradability are founded on accepted standards. The Institute for Local Self-Reliance (ILSR) is in the process of completing a study of various degradable polymers. The study is examining the commercial status of various technologies and evaluating the biodegradability claims made by various companies.

PHB/V Targets Markets in Europe

Polyhydroxybutyrate/valerate copolymers are being produced by Zeneca Bio Products of Wilmington, Delaware, a spin-off company from International Chemicals, Inc. Zeneca's plant is located in the United Kingdom and has capacity of about 600 metric tons (1.3 million pounds) of resin per year. PHB/V copolymers are produced by fermentation of a sugar feedstock (glucose is currently being used) by a naturally occurring microorganism. Zeneca's resulting BIOPOL resin can be designed to have many different physical properties, depending on the hydroxyvalerate content. PHB/V completely degrades in a biologically active environment to carbon dioxide and water. Zeneca is currently working with USDA's Agricultural Research Service in modifying the polymer matrix with various additives and testing degradability of the resulting polymers.

BIOPOL resins can be converted into various types of plastic products, depending on the physical properties of the resin used. The first major product was a biodegradable shampoo bottle, which was developed about 5 years ago. However, because BIOPOL resin prices, which range from $3 to $6 per pound, are somewhat higher than prices for other degradable resins, the number of markets for BIOPOL may be limited. According to a Zeneca representative, major target products are likely to be plastic films and coatings. The major markets for BIOPOL currently are in Europe and, to some extent, Japan. Environmental regulations in several European countries, particularly Germany, favor biodegradable products.

Starch-Based Technology Benefits from Corporate Mergers

Recent corporate mergers and technology improvements are helping starch-based polymers to overcome some of the previous difficulties faced by the industry. Moisture sensitivity has been a major concern for starch-based polymers. Developments in various additives have helped many companies create resins that are water resistant. Some of the additives, known as masterbatch additives, incorporate starch, synthetic linear polymers, plasticizers, and other additives that trigger and/or accelerate the degradation process. A careful study of degradability and toxicity must be made when evaluating resins containing these particular additives.

Many starch-based resins can be processed on conventional plastic-molding equipment and, depending on the properties of the specific resin, can be converted into virtually all types of plastic products. These include but are not necessarily limited to: compost bags (lawn and leaf), disposable foodservice items (cutlery, plates, cups, etc.), packaging materials (loosefill, films, etc.), coatings (lamination, paper coatings, etc.), and specialty items, such as golf tees, agricultural films, and various medical products. The amounts of starch and other additives used in the polymer generally depends on the desired properties of the end product.

There have been many corporate developments in the starch-based polymer industry since pharmaceutical giant Warner-Lambert closed its Novon division in November 1993. At the time, Novon was the leading U.S. producer of starch-based biopolymers, with a 100-million-pound-per-year capacity. In January 1995, EcoStar International, a company with a background in biodegradable compounds and additives, acquired Novon from Warner-Lambert and formed Novon International, Inc. In February 1995, Novon International was in turn acquired by Churchill Technology, Inc., a British company that owns patents on nonagriculturally based, biodegradable resins. All three corporate entities have been consoli-

dated into the Novon International facilities in Buffalo, New York, and will continue to be known as Novon International, Inc.

The starch-based polymer currently available from Novon International is called Novon, and it is manufactured primarily from corn or potato starch, along with smaller amounts of foodgrade additives (although not intended for human consumption). This resin is suitable for manufacturing nearly all plastic products, and is currently priced around $2.25 to $2.50 per pound. Also available from Novon International is a starch-based masterbatch additive called Novon-Plus. Novon-Plus is intended to be mixed with synthetic polymers to create nearly any plastic product, while making the product more degradable than the traditional synthetic plastic. A typical product may be about 43 percent starch, 50 percent synthetic polymer, and 7 percent proprietary ingredients. Current pricing for Novon-Plus additives are about $1.60 to $1.70 per pound.

Other companies are developing starch-based polymers as well. Founded in February 1995, BioPlastics, Inc., is using technology from Michigan State University, licensed through the Michigan Biotechnology Institute (MBI), to create a resin called ENVAR. A for-profit subsidiary of MBI, Grand River Technologies, Inc., also is entering the starch-based resins market. Grand River has joined with Japan Corn Starch Company, Ltd., to form EverCorn, Inc., to market cornstarch-based EverCorn resin. EverCorn completed a $1.8-million research and development phase in July 1995, and has a pilot-scale operation in place to provide customers with samples in 1,000-pound quantities. The company hopes to have a 10-million-pound, semi-works plant operating by late 1996, and plans for a 250- to 500-million-pound commercial plant in 1998.

Cargill Leads the Way in PLA-Based Resins

The third major biobased polymer technology is based on polylactic acid. PLA polymers are generally derived by fermenting carbohydrate crops, such as corn, wheat, barley, cassava, and sugar cane. Companies such as Archer Daniels Midland and Cargill produce lactic acid (via starch fermentation) as a coproduct of corn wet milling, which can be converted to PLA. PLA-based polymer resins are completely biodegradable under compost conditions. PLA can be hydrolyzed using only water back to lactic acid, and can be repolymerized if desired. PLA-based resin also can be degraded by marine microbes into water and carbon dioxide. However, PLA is not water soluble. PLA-based polymers can be modified to suit nearly all plastic applications from disposable foodservice items to coatings for paper.

The largest producer of PLA-based polymers is Cargill. The company's PLA-based resins, called EcoPLA, are commercially available from its plant in Savage, Minnesota. This plant has an annual capacity of about 10 million pounds of resin, but Cargill plans to open a larger facility with a capacity of 100 to 300 million pounds in Blair, Nebraska, by 1998. Current prices for EcoPLA resins range from $2 to $5 per pound, depending on grade, but, with the larger facility, future prices are expected to be around $1 per pound.

Two other U.S. firms and several Japanese firms also have been developing PLA-based polymers for the past few years. The U.S. firms are Ecochem, a joint venture between DuPont and ConAgra, and the Chronopol Company, a subsidiary of ACX Technologies, which is headquartered in Golden, Colorado. Ecochem and Chronopol have formed a patent-holding venture called EcoPol L.L.C., but the companies will continue to operate independently. Chronopol is currently at the pilot-plant stage and does not have commercial quantities of resin available, and Ecochem is not pursuing resin production at this time. According to industry sources, three Japanese firms—Dainipon Ink and Chemicals, Inc.; Mitsui Toatsu Chemicals, Inc.; and Shimadzu Corporation—are planning pilot plants.

ILSR estimates that only 1.1 percent of the plastics produced in 1996 will be partly or wholly derived from plant matter. This means that, for the near future, companies making PHB/V-, starch-, and PLA-based polymers will continue to focus on niche markets. These markets will serve customers who are willing to pay a higher price for products that are environmentally friendly, or specialty uses where a higher price is not a limiting factor. PLA technology, for example, has been used for years in specialty medical applications, such as bioabsorbable sutures and bone implants. However, PLA's high price compared with petroleum-based resins has prevented its use in vast commercial applications.

Though recent advances in production technology have helped lower some resin prices and make biobased polymers function more like traditional petroleum-based products, prices of biodegradable resins are still significantly higher than those for petroleum-based plastics. In addition, companies and communities must be willing to provide the proper composting facilities for biodegradable polymers. Otherwise, they will end up in the solid waste stream with other trash and will not degrade as designed. The long-term outlook for biobased polymers is still uncertain, but is likely dependent on future worldwide regulatory developments and continued improvements in cost-lowering technologies.

Xanthan Gum Popular in Food and Industrial Applications

Discovered in 1963 at USDA's Northern Regional Research Center (now called the National Center for Agricultural Utilization Research), xanthan is now one of the most popular commercially produced gums. It was first derived from the bacterial action of *Xanthomonas campestris* on plants, primarily those in the cabbage family. With the advent of viscous fermentation technology in the early 1970's, this high-molecular-weight polysaccharide is now produced from cornstarch.

Gums is the common term for hydrocolloidal gels—polysaccharides that have an affinity for water and exhibit binding properties with water and other organic/inorganic materials. Traditionally, gums have been derived from a wide variety of plants. More recently, however, other valuable polysaccharides have been identified that are produced from microbial sources (table 3). Hydrocolloidal gums also can be produced from marine plants and cellulosic materials.

Kelco (San Diego, California), a division of Monsanto Company, and Archer Daniels Midland Company (Decatur, Illinois) are the two U.S. producers of xanthan gum. U.S. capacity in 1994 was estimated at 57 million pounds. Based on trade data and new-plant construction information, U.S. production capacity in 1995 is estimated at 77 million pounds. (Producers will not verify actual capacities; plant capacity and production volumes are considered proprietary.) If the companies' four plants are operating at full capacity, an estimated 5 million bushels of corn will be used to produce xanthan gum in 1995.

Xanthan gum also is imported from a Kelco plant in the United Kingdom, a Jungbunzlauer plant in Austria, and several French plants operated by Rhone-Poulenc and Sandfi Bio-Industries. Both Jungbunzlauer and Rhone-Poulenc have expressed interest in producing xanthan gum in the United States.

Xanthan gum is used in a variety of industrial and oil-field applications, pharmaceutical and personal care items, and processed foods (table 4). Its broad usefulness as a thickening and stabilizing agent makes xanthan gum one of the most attractive products of the over $2.5-billion hydrocolloid mar-

Table 3--Commercial gums produced in the United States, by type of source material

Microbial fermentation	Marine plants	Terrestrial plants	Cellulose sources
Dextran	Agar	Guar gum	Carboxymethyl cellulose
Gellan gum	Alginates	Gum arabic	Hydroxypropyl cellulose
Rhamsan gum	Carrageenan	Gum tragacanth	Hydroxyethyl cellulose
Welan gum	Furcellaran	Karaya gum	
Xanthan gum		Locust bean gum	
		Pectin	

Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., McLean, VA, July 1995.

Table 4--Xanthan gum's properties and end-product applications

Property	Industrial applications	Oil-field applications	Pharmaceutical and personal-care applications	Food applications
Emulsifying	Abrasives, agricultural products, pulp, and paper	Improves drilling-hole cleaning and penetration rates	Medicated syrups (e.g., dextromethorphan) and shampoos	Batters and beverages
Stabilizing	Ceramics	--	Liquid soaps and toothpastes	Pie fillings, dairy products, frozen foods, sauces, and gravies
Thickening	Cleaners, polishes, paints, and textile inks	Debris suspension	Shampoos and liquid soaps	Batters and sauces
Gelling	Coatings and adhesives	--	Toothpastes	Confectionery
Film forming	--	--	--	Barrier coatings

-- = Not applicable.
Source: Irshad Ahmed, Booz, Allen & Hamilton Inc., McLean, VA, July 1995.

ket. The outlook for xanthan gum is bright in both food and industrial applications. However, industrial uses are increasing at a faster rate than food uses. Between 1983 and 1993, gums derived from microbial fermentation of starch have enjoyed strong market success, with average growth rates of 9 percent annually.

List prices for both food-grade and industrial-grade xanthan gum were stable between 1989 and 1992. Prices increased in 1993 for both categories by approximately 10 percent. Food-grade prices rose from $5.50 per pound to a current price of over $6.20 per pound. The price of xanthan for industrial applications varies considerably, depending upon the grade. On average, industrial-grade xanthan sells for $5 per pound, while refined grades for special applications command over $8 per pound.

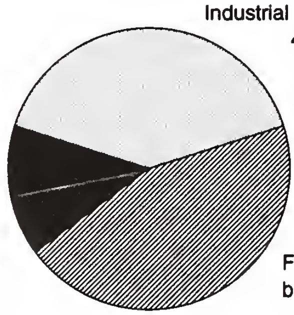
Xanthan Gum Has Many Industrial Uses

Although food and beverages account for the largest end-use category, xanthan gum also is used in a wide variety of industrial applications (figure 1). Industrial xanthan gum products are manufactured to meet formulation criteria, such as long-term suspension and emulsion stability in alkaline, acid, and salt solutions; temperature resistance; and pseudoplasticity. In addition, a range of differentiated xanthan gum products are designed to meet specific applications requirements. These include a transparent grade to improve solution clarity and a dispersible grade for low-shear mixing conditions. Examples of xanthan gum's many industrial uses include:

Agricultural products. Xanthan gum is an excellent suspension agent for pesticides, fertilizers, and liquid-feed supplements. It helps control spray drift and cling, which increase the contact time between the pesticide and the crop.

Ceramics. Xanthan gum is used as a suspending agent in electrode coatings, as well as in glazes and binding agents for tiles and sanitary ware. It also prevents sagging and pinholing in these products.

Figure 1
End Uses of Xanthan Gum in 1994 1/



1/ U.S. capacity in 1994 for xanthan gum is estimated at 57 million pounds.
Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., Mclean, VA, July 1995.

Cleaners. Xanthan gum's flow properties and broad pH stability make it the thickener of choice in products such as highly alkaline drain, tile, and grout cleaners; acidic solutions for removing rust and metal oxide; graffiti removers; aerosol oven cleaners; toilet-bowl cleaners; and metal-cleaning compounds. Xanthan gum provides cling to vertical surfaces, as well as easy removal.

Coatings. The pseudoplastic properties of xanthan gum provide excellent texturing in ceiling-tile coatings and paints with a high-solids content, ensuring in-can stability, ease of application to the wall, and retention of the textured finish. Xanthan gum thickens latex paints and coatings, and uniformly suspends zinc, copper, and other metal additives in corrosion coatings.

Oil-drilling aids and fluids. Xanthan gum is used as a thickener in conventional drilling aids that flush pieces of rock away from the drill bit. Xanthan-formulated systems provide optimum hydraulic efficiency of drilling fluids. It reduces pressure losses within the drill string, allowing maximum hydraulic power to be delivered to the bit. As a result, penetration rates can be increased. Historically, secondary and tertiary oil-well drilling have been significant users of xanthan gum.

Paper. Xanthan gum is used as a suspension aid or stabilizer in the manufacture of paper and paperboard, particularly when intended for contact with food.

Personal care applications. Xanthan gum improves the flow properties of shampoos and liquid soaps and promotes a stable, rich, and creamy lather. It is an excellent binder for all toothpastes, including gel and pumpable types. Ribbon quality and ease of extrusion are improved as well.

Pharmaceutical applications. Xanthan gum stabilizes suspensions of a variety of insoluble materials such as barium sulfate (for x-ray diagnoses), complexed dextromethorphan (for cough preparations), and thiabendazole. It is playing an increasingly important role in controlled-release applications, where disintegration of the tablet is the primary mechanism of release.

Polishes. Xanthan gum suspends solids in leather and silver polishes, provides lubricity to lotions and heavy creams, and stabilizes polish emulsions.

Textiles. Xanthan gum forms temperature-stable foams for printing and finishing, and acts as a flow modifier for dyeing heavy fabrics. Its flow properties and temperature stability make it ideal for carpet jet printing, where it ensures sharp print definition, absence of frosting, and trouble-free operation. [Irshad Ahmed, (703) 917-2060; Charles Plummer, (202) 219-0717; Allen Baker, (202) 219-0360; and John McClelland, (202) 501-6631]

Surfactants and Biodiesel Expand the Use of Vegetable Oils

The use of agriculturally based surfactants is increasing in existing products and processes and in newer applications. U.S. transit operations will be able to use biodiesel to meet air-quality regulations, without any change in operability and maintenance, if it is approved as a certified technology for the Urban Bus Retrofit Rebuild Program. In the European Union, biodiesel production and commercial use expanded in 1994 and is expected to intensify in 1995. Crambe growers in North Dakota have contracted with the Archer Daniels Midland plant in Enderlin, North Dakota, to toll process their 1996 crop.

Surfactants Use Increasing in Traditional and New Applications

Surfactants are compounds that change the surface and interfacial tension of materials. As ingredients in soaps and detergents, they increase the wetting ability of water so that it can more easily penetrate fabric and remove dirt particles. In paints, they improve adhesion of paint particles to the surface being painted. Surfactants were first manufactured by the soaps and detergents industry for their products. As more uses were discovered, an independent industry arose.

Driven both by environmental regulations and expanding niche markets, the use of surfactants is increasing both in existing products and processes and in newer applications. With 23 States either partially or completely banning phosphates in laundry detergents and 7 others contemplating bans, detergent manufacturers are turning to environmentally friendly, surfactant-based systems to achieve maximum cleaning characteristics. The industry is meeting consumer demands for biodegradable products with the use of surfactants derived from vegetable oils and fats. The current popularity of superconcentrated detergents also has boosted the demand for these surfactants.

Surfactants can be made using either petrochemical feedstocks or agricultural materials, such as vegetable oils, animal fats, and starches. Many different vegetable oils are, or can be, used to make surfactants (table 5). Coconut and palm kernel oils are popular feedstocks. Coconut oil prices have ranged from 30.5 to 35.6 cents per pound during the first 7 months of 1995 (table 35), while palm kernel oil prices varied from 31 to 37 cents per pound (table 42). Ethylene, a major petroleum feedstock for surfactants, sells for 20 to 22 cents per pound.

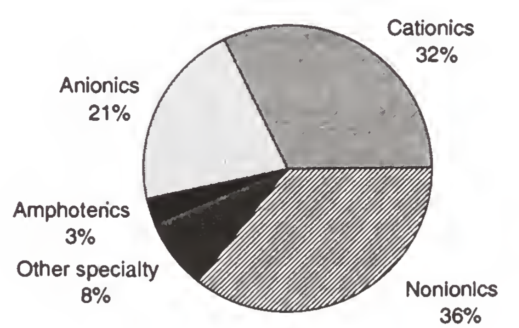
Table 5--Vegetable oils that are, or can be, used by U.S. surfactant manufacturers

Currently used	Potentially feasible	
Castor	Bladderpod	Linseed
Coconut	Buffalo gourd	Meadowfoam
Palm	Crambe	Safflower
Palm kernel	Cuphea	Vernonia
Rapeseed	Euphorbia	
Soybean	Jojoba	
Sunflower	Lesquerella	

There are four major types of surfactants: nonionics, cationics, anionics, and amphoterics (figure 2). About 15 percent of anionics come from plant and animal sources, while over 30 percent of nonionics are made from these natural feedstocks. Overall, an estimated 20 percent of all surfactants are derived from natural raw materials. In many applications, such as laundry detergents, surfactants derived from agricultural and petroleum feedstocks are interchangeable. Industrial grade surfactants usually sell for under 50 cents per pound, while specialty surfactants with applications in cosmetics and textiles go for $1 per pound and higher.

While surfactants have long been considered environmentally neutral products, recent studies have found traces of carcinogens—such as nitrosamines, dioxanes, and ethylene oxides—in some surfactants derived from petrochemical feedstocks. These concerns have spurred the replacement in detergents of surfactants containing petrochemical-derived branched-chain alcohols with surfactants containing straight-

Figure 2
Market Share in 1994 by Type of Surfactant 1/



1/ Approximately 7.5 billion pounds of surfactants were used in 1994.
Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., Mclean, VA, August 1995.

chain fatty alcohols derived from vegetable oils. Straight-chain alcohols also biodegrade more easily than branched chain compounds.

Henkel Corporation of Gulph, Pennsylvania, a leading surfactant manufacturer, is producing a new line of vegetable oil-based surfactants for the soaps and detergents industry. The surfactants are made from corn, coconut, and palm kernel oils, and are marketed under the trade name Plantaren. Henkel's Cincinnati, Ohio, plant produces 27,500 tons of Plantaren per year.

More than 10 large surfactant manufacturers are using natural feedstocks to commercially produce a wide variety of surfactants with potential to supply almost all segments of the organic chemicals industry. For example, Hoechst Celanese produces a group of ethoxylate-type surfactants, called Grenapol 26-L, at its Charlotte, North Carolina, specialty chemicals plant that are made from coconut and palm kernel oils. Leading surfactant manufacturers that use natural raw materials include Witco Corporation, Henkel Corporation, Ethyl Corporation, and Proctor & Gamble Company.

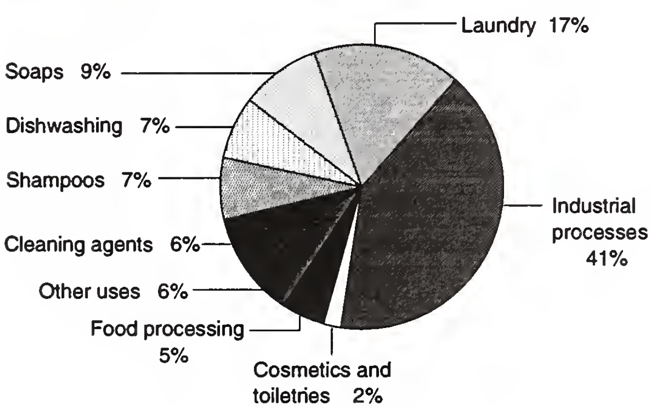
In 1994, U.S. surfactant industry shipments were valued at $19 billion, an increase of over 3 percent in constant dollars from 1993. U.S. surfactant consumption in 1994 was roughly 7.5 billion pounds. Industrial processes accounted for the largest market share, followed by laundry and soap (figure 3). The industry employs over 9,000 people in the United States. In 1995, surfactant markets are expected to exceed $20 billion.

New Markets Are Being Developed

One of the fastest growing segments of surfactant markets is specialty surfactants, which are designed with properties to meet specific end-product requirements. The introduction of two-in-one and three-in-one products—such as shampoos that combine shampoo, conditioner, and coloring agents in one formulation—has opened up new markets for surfactants derived from natural materials. The markets for specialty surfactants has been growing at a rate of 10 percent per year since 1990. In 1994, 1.5 billion pounds of specialty surfactants, valued at $1.7 billion, were consumed in the United States.

Figure 3

Utilization of Surfactants in 1994 by Type of End Product[1/]



1/ Approximately 7.5 billion pounds of surfactants were used in 1994.
Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., Mclean, VA, August 1995.

Surfactant-based systems are increasingly being used as a substitute for solvents, bleaches, and other processing chemicals in the pulp and paper, metal cleaning, and chemical processing industries where the key property requirements are bleaching, hydrolysis, and/or surface chemistry. For example, Interchem Industries, Inc., of Overland Park, Kansas, has developed several methyl ester-based solvents that are effective as degreasers and cleaning agents for machinery and removing graffiti from walls and sidewalks. Surfactant-based techniques also are being developed for replacing lubricating systems. Surfactants derived from vegetable oils nearly eliminate toxic pollutants when used as an alternative to conventional boron-based petrochemical equivalents.

The surfactant industry is forecast to grow 3 to 4 percent annually during the next 5 years. Manufacturers will attempt to satisfy the demand for more effective cleaning agents by introducing new all-purpose cleaners. Environmental concerns will force producers to look for natural substitutes, such as agricultural-based surfactants, for fluorocarbons and chlorinated hydrocarbons used as degreasers. (See the Specialty Plant Products Sections for other natural alternatives.)

Regulations and Environmental Benefits Boost Biodiesel's Prospects

Twin Rivers Technology, Inc., of Quincy, Massachusetts, has submitted a certification package to the U.S. Environmental Protection Agency (EPA) that includes the use of biodiesel fuel for approval as a "certified technology" for the Urban Bus Retrofit Rebuild Program. Finalized in 1993, the program is designed to reduce particulate-matter exhaust emissions from older-model urban buses (model year 1993 and earlier). (See the special article on biodiesel for more information on the program.) To date, only an oxidation catalyst developed by Engelhard, a New Jersey-based technology company, has achieved certification. Twin Rivers' proposed technology uses a straight 20/80-percent biodiesel/diesel blend, a 20-percent blend with a minor engine timing change, or the blend in conjunction with an oxidation catalyst.

Urban transit operators will be making their decision on compliance options for the retrofit program by the end of 1995. If approved, biodiesel's certification will enable transit operators to meet Clean Air Act regulations without any significant change in operations or maintenance. In a recent survey of urban transit managers, one-fifth indicated that biodiesel is their number one alternative fuel. Biodiesel ranked second in the survey behind compressed natural gas as the alternative fuel of choice for urban bus systems (*1*).

The Energy Policy Act of 1992 (EPACT) affects virtually all aspects of U.S. energy markets. Under the auspices of the U.S. Department of Energy (DOE), EPACT provisions encourage increased use of renewable energy and more efficient use of fossil fuels and nuclear energy, which will increase the competitiveness of these sectors. Under the umbrella of re-

newable energy, biodiesel is covered under several sections of the law, such as Alternative Fuels Utilization, Biofuels User Facility, and Biofuels Renewables. DOE's Biofuels Systems Program views biofuels as a win-win strategy that could provide energy security, improve the environment, increase farm income, and promote rural development (2).

On July 31, 1995, DOE published a notice in the *Federal Register* announcing a limited reopening of the public comment period for EPACT's Alternative Transportation Fuels Program. During the original public comment period from February 28 to May 1, 1995, many respondents requested that biodiesel specifically be included in DOE's regulatory definition of "alternative fuel." DOE is considering amending the proposed definition to include neat biodiesel, with a caution that this proposal does not relieve alternative fuel producers from complying with other federal, state, or automobile manufacturer requirements. DOE also is considering comments urging the inclusion of biodiesel blends in the definition of "alternative fuel." EPACT Section 301 authorizes such an addition for fuels that are "substantially not petroleum and would yield substantial energy security and environmental benefits."

One of EPACT's advantages is its complementarity with federal environmental regulations and programs. For example, biodiesel can help reduce tailpipe emissions of hydrocarbons, carbon monoxide, and particulate matter. It does not contain sulphur or harmful aromatics. Plus, it is nontoxic and biodegradable. Thus, it could help diesel users comply with Clean Air Act regulations, such as the Urban Bus Retrofit Rebuild Program and the Clean Fuel Fleet Program. EPACT's biofuels provisions also complement the U.S. Climate Change Action Plan, which aims to mitigate the greenhouse effect caused by the build up of carbon dioxide (CO_2) and other trace gases in the atmosphere.

Test Results Further Quantify Biodiesel's Environmental Benefits

Test results from two independent studies further validate biodiesel's reputation as a health- and environmentally friendly fuel for mining and marine applications. In the first study, the French Oilcrop Association ONIDOL, together with the Government of France, conducted engine-durability and emissions-level testing using biodiesel produced from rapeseed oil. Results show that unregulated exhaust emissions of gaseous polycyclic aromatic hydrocarbons (PAH's) declined significantly with increased percentages of rapeseed biodiesel in the fuel blend (table 6). Particulate PAH's decline as well for a 30-percent biodiesel blend. PAH's are organic compounds adsorbed on diesel particulate matter that have received considerable attention because of their potential mutagenic and carcinogenic properties.

The second study, which was conducted by the University of Idaho for USDA's Cooperative State Research, Education, and Extension Service (CSREES), demonstrates that biodiesel fuels are readily biodegradable in an aquatic environment. Biodegradability is an issue for water quality and ecosystem effects in case the fuel enters an aquatic environment in the course of its use or disposal. Not only are oil spills a hazard

Table 6--Exhaust emissions of polycyclic aromatic hydrocarbons (PAH'S) from urban buses burning diesel and biodiesel blends

Pollutant	Amount of biodiesel in the fuel 1/ 0 percent	30 percent	50 percent
		ug/cycle	
Gaseous PAH's			
Napthalene	331,654	253,398	384
Methyl-2 napthalene	10,280	3,841	329
Acanapthylene	1,268	376	268
Fluorene	1,864	463	368
Methyl-1 fluorene	2,380	297	584
Anthracene	4,301	904	873
Fluoranthene	783	172	128
Pyrene	816	121	80
Particulate PAH's			
Fluoranthene	144	105	124
Pyrene	139	105	162
Benzo (ghi) fluoranthene	42	32	59
Benzo (a) anthracene	19	15	29
Chrysene + triphanylene	69	42	74
Benzo (k) fluoranthene	23	12	20
Benzo (b) fluoranthene	8.2	3.4	6.7
Benzo (c) pyrene	18	15	20
Benzo (a) pyrene	5.1	5.4	9.7
Benzo (ghi) perylene	11	7.2	23
Dibenzo (ah) anthracene	3	0.89	1.9

1/ The biodiesel used was rapeseed methyl ester.
Source: Frederic Staat and Paul Gateau, "The Effects of Rapeseed Oil Methyl Ester on Diesel Engine Performance, Exhaust Emissions and Long-Term Behavior--A Summary of 3 Years of Experimentation," paper presented at the SAE International Congress and Exposition, February 27-March 2, 1995, in Detroit, MI, SAE International, Warrendale, PA, technical paper 950053.

to natural waterways, diesel-fueled vessels and equipment operating in an aquatic environment often leak small amounts of fuel into the surrounding ecosystem.

Using CO_2 evolution tests in a shaker flash system, various biodiesel fuels and petroleum diesel were added to distilled water containing small amounts of organic-matter-rich soil, raw sewage water, yeast, and a nutrient supply (nitrogen and phosphorus). The amount of CO_2 given off indicates how much of the substrate has been metabolized. Results show that rapeseed- and soybean-oil-based biodiesel degraded at about the same rate as dextrose and three times faster than petroleum-based diesel (table 7). In addition, more biodiesel disappeared after 28 days than had raw soybean or rapeseed oil. In tests of biodiesel/diesel blends, the presence of biodiesel prompted and accelerated the degradation of the entire blend (table 8). After 7 days, 25 percent of a 20-percent biodiesel blend had degraded into CO_2 and water, versus 12 percent for diesel fuel.

European Biodiesel Production Expands

Unlike the limited use of biodiesel in the United States, biodiesel production and commercial use in the European Union (EU) expanded in 1994 and is expected to intensify in 1995. Rapeseed (mostly canola) grown for biodiesel production amounted to approximately 1.2 million metric tons in 1994, almost a three-fold increase over 1993. This expansion is due to EU agricultural policies that allow farmers to grow oilseeds and certain other crops for industrial uses, such as biodiesel production, on set-aside land. The EU's Common

Table 7--Biodegradability of various types of biodiesel, rapeseed oil, soybean oil, diesel fuel, and dextrose 1/

Days	Rapeseed ethyl ester	Rapeseed methyl ester	Soybean ethyl ester	Soybean methyl ester	Rapeseed oil	Soybean oil	Diesel fuel	Dextrose
				Percent CO2 evolution 2/				
0	0	0	0	0	0	0	0	0
7	69.01	66.32	67.68	68.40	58.39	60.57	13.20	59.84
14	79.15	80.72	78.40	77.83	70.47	70.12	21.04	80.19
28	86.92	88.49	86.40	85.54	78.48	75.95	26.24	87.79

1/ Rapeseed and soybean methyl and ethyl esters are types of biodiesel. Dextrose was included for comparison. 2/ Biodegradability is measured by the percent of CO2 given off as microbes degrade the substrate.

Source: Xiulin Zhang, Charles L. Peterson, Daryl Reece, Gregory Moller, and Randal Haws, "Biodegradability of Biodiesel in the Aquatic Environment," paper presented at the 1995 ASAE Meeting, June 18-23, 1995, Chicago, IL, American Society of Agricultural Engineers, St. Joseph, MI, paper no. 956742.

Table 8--Biodegradability of biodiesel/diesel blends

Days	Biodiesel 1/	Percent biodiesel/diesel 80/20	50/50	80/20	Diesel
		Percent C02 evolution 2/			
0	0	0	0	0	0
7	64.09	52.33	37.85	25.24	12.08
14	77.51	61.26	45.74	31.59	14.96
28	84.37	67.82	51.90	35.67	18.18

1/ Rapeseed ethyl ester. 2/ Biodegradability is measured by the percent of CO2 given off as microbes degrade the substrate.

Source: Xiulin Zhang, Charles L. Peterson, Daryl Reece, Gregory Moller, and Randal Haws, "Biodegradability of Biodiesel in the Aquatic Environment," paper presented at the 1995 ASAE Meeting, June 18-23, 1995, Chicago, IL, American Society of Agricultural Engineers, St. Joseph, MI, paper no. 956742.

Agricultural Policy requires producers of arable crops (grains, oilseeds, and protein crops) to set aside a portion of their arable crop base to receive support payments. Farmers receive a set-aside premium for industrial oilseeds production in addition to payments from seed sales. The average set-aside premium for arable crops in 1994 was about $138 per acre.

The amount of set-aside land on which industrial oilseeds were grown for the production of biodiesel increased from 204,000 hectares in 1993, the first year of the program, to 621,000 hectares in 1994. In 1995, the forecast is around 900,000 hectares (table 9). The main beneficiaries of the set-aside program for biodiesel are EU rapeseed and sunflowerseed producers. In Austria, an early leader in European biodiesel development, farmers plant both rapeseed and sunflowers, while rapeseed is popular in France and Germany and sunflowers in Italy.

Although most biodiesel in Europe is used in urban public bus and truck fleets, it is also used to fuel farm equipment, as a heating fuel, solvent, hydraulic oil, and lubricant. Since biodiesel has less of an environmental impact compared with petroleum-based products, most European countries that commercially produce biodiesel—France, Germany, Italy, and Austria—offer some form of tax break to reduce production costs to make biodiesel competitive at the pump. High European excise taxes on petroleum products raise the retail price of diesel fuel to a level that allows higher cost biodiesel that is exempt from excise taxes to compete. For instance, if 85 percent of the excise tax were removed, the prices of diesel and biodiesel would be competitive (figure 4).

Greater biodiesel production also has been made possible by an expansion in processing capacity. In 1994, EU crushing plants could process approximately 350,000 tons of oilseeds. This capacity is expected to double in the near future due to continued program assistance from national governments, oil companies, producer cooperatives, and oilseed promotion boards. Despite the expected capacity expansion, production is restrained by uncertainty over limits on industrial oilseed production agreed upon by the EU and the United States.

Concerned about the competition for soybean exports from oilseed meals produced as coproducts, the United States sought limits on the amount of oilseeds grown on European set-aside land. Under the Blair House Agreement, signed by the EU and United States in 1992, the EU agreed to limit the production of industrial oilseeds on set-aside land to the equivalent of 1 million tons of soybean meal, which is roughly equal to 2.3 million tons of rapeseed. With the EU likely to reach its industrial-oilseed production limit this year and the uncertainty on how these limits will be administered, biodiesel producers are hesitant to further increase productive capacity.

Crambe Farmers Search for Crushing Facility

During the past few years, farmers in North Dakota, in cooperation with National Sun Industries, began developing a significant crambe industry. Like many farmers across the United States, these farmers were attempting to diversify crop production and market opportunities. Crambe acreage increased from 2,200 in 1990 to 55,500 in 1993, then declined to 43,900 acres in 1994 (table 10). No commercial acreage was planted in 1995, primarily because much of the crambe oil produced last year had not been sold by the spring planting date. However, a few fields of crambe were planted and harvested in 1995 for seed stock. As with many new crops, it is difficult to match supply and demand. In the case of crambe, crop production grew faster than the demand for the oil as an industrial feedstock. Most crambe oil is processed into erucamide, which is used as a slip agent for plastic wraps and bags.

Despite the lack of commercial acreage in 1995, the crambe growers, organized as the American Renewable Oilseed Association (AROA), continue their efforts to commercialize and market crambe. Previously, National Sun Industries processed crambe in their plant in Enderlin, North Dakota. However, the company decided in 1994 to discontinue crushing operations and concentrate on value-added processing of oilseed products. As a result, National Sun leased the Enderlin plant to Archer Daniels Midland Company (ADM), which is using it to process sunflowers. AROA personnel expect to produce about 40,000 acres of crambe in 1996, with the crop

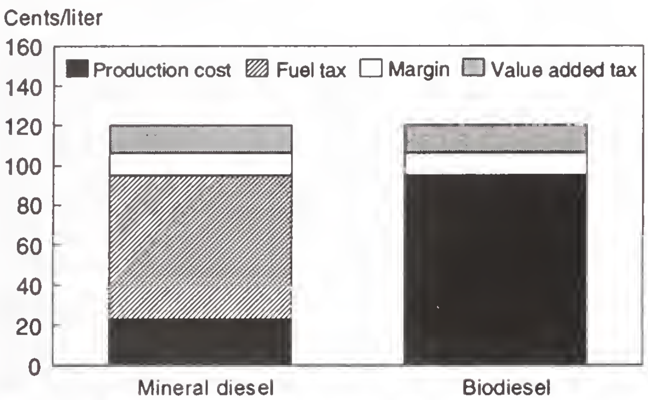
Table 9--Area and production of industrial oilseeds in the European Union 1/

Crop	Area			Production		
	1993-94	1994-95	1995-96 2/	1993-94	1994-95	1995-96 2/
	Hectares			Metric tons		
Rapeseed	172,000	482,000	800,000	472,000	1,236,000	2,328,000
Sunflowerseed	32,000	139,000	100,000	64,000	243,000	134,000
Total	204,000	621,000	900,000	536,000	1,479,000	2,462,000

1/ Refers to oilseeds produced for nonfood uses on set-aside land. 2/ Forecast.

Figura 4

Price of European Biodiesel Is Competitive at 85-Percent Tax Reduction



Sourca: Tadashi Murayama, "Evaluating Vagatabla Oils as a Diasal Fual," Inform, Vol. 5, No. 10, October 1994, pp. 1138-45.

Table 10--Crambe acreage, United States, 1990-95 1/

Year	Area	Yield 2/
	Acres	Pounds/acre
1990	2,200	1,300
1991	4,500	1,338
1992	24,000	1,138
1993	55,500	1,011
1994	43,900	1,300 3/
1995	0	0

1/ Commercial acreage. 2/ North Dakota only. 3/ Estimated

to be toll processed by ADM at their Enderlin plant. AROA has contracted with Witco Chemical to buy the crambe oil and will market the meal on its own.

HEADE Provided Crambe with Crucial Support

Because of the market potential for products containing, or derived from, erucic acid (the major fatty acid in crambe and industrial rapeseed oils), an effort by universities, government, and private industry was initiated in December 1986 to help develop crambe as a major crop in the United States. Participants recognized that, since erucic acid was used only in minor quantities in the United States, any attempt to develop a large-scale commercial industry would need to coordinate crop production, processing, and product/market development. The Crambe Project, as the effort was called, was supported by Iowa State University, the Kansas Board of Agriculture, Kansas State University, the University of Missouri, and New Mexico State University, plus USDA's Agricultural Research Service and CSREES. A special effort was made to involve private industry.

The Crambe Project became the High Erucic Acid Development Effort (HEADE) in 1990 and research was expanded to include industrial rapeseed. Eventually, consortium members also included the land grant universities of Georgia, Idaho, Illinois, Nebraska, and North Dakota. While it was never incorporated or organized as a legal entity, it was a very effective multistate group whose scientists operated in multidisciplinary teams.

Some of HEADE's funding came from a Special Grant appropriation, which was administered by CSREES. Federal funds were matched by state funding on approximately a dollar-for-dollar basis. Federal appropriations for the project reached $500,000 in the early 1990's, but funding was discontinued in fiscal 1995. Thus, HEADE lost funding and its primary private sector proponent at about the same time.

A review of HEADE's structure, activities, and progress show how the consortium was successful in its development efforts and how it may be an appropriate model for the development of other new crops. The HEADE structure included a management committee, plus subcommittees for production, processing, and marketing/economics. HEADE's priorities were reviewed annually by the management committee, with significant input from subcommittee members, private-industry participants, others knowledgeable about high-erucic-acid oils and their products, and those knowledgeable about the agronomics of crambe and industrial rapeseed.

Once priorities and the level of federal funding were identified, a request for proposals was issued. The proposals received were evaluated and prioritized by peer review panels for each of the subcommittees. The subcommittees' ranked proposals were then collectively considered and ranked by the management committee, according to quality, potential for contribution to the HEADE project mission, and the potential to dramatically increase the level of production of these crops and use of high-erucic-acid oils in the United States. Those receiving the highest ranking were funded. Typically, 15 to 20 projects were funded annually, at levels ranging from $5,000 to $20,000 each.

Production advances outpaced those in processing and product development. The combined efforts of National Sun Industries and North Dakota State University expanded crambe acreage in North Dakota from test plots in 1989 to 55,500 acres in 1993. While this was a prime example of

private-public cooperation, the failure to develop additional markets for high-erucic-acid oils resulted in excess supplies.

Significant advances have been made in plant breeding. A major breeding program for crambe is underway at North Dakota State University, while the industrial rapeseed work is located at the University of Idaho. The University of Georgia also expanded their breeding program for industrial rapeseed and canola. These programs, plus activities by agronomists and plant scientists at each of the member universities, have resulted in significantly higher yields, improved winter hardiness, and better knowledge of planting and harvesting dates, fertilizer needs, harvesting methods, and other relevant factors.

The processing subcommittee conducted pilot-scale tests and determined that extrusion processing of whole and dehulled crambe and rapeseed provided excellent seed preparation for solvent extraction of both crops. The subcommittee provided advice to National Sun when the company began crushing crambe by prepress-solvent extraction in their Enderlin mill. Research on the uses of defatted crambe meal in beef cattle rations aided marketing of the meal to feeders and feed formulators. The subcommittee also sought to increase the value of crambe meal by examining ways to extract glucosinolates from the meal. Projects were funded to evaluate glucosinolates as potential herbicides, nematicides, insecticides, fungicides, and chemoprotectants/antitumor agents.

Product development efforts were restricted by the level of HEADE funding, but numerous research proposals were considered and a number funded. The types of products explored include surfactants, lubricants, paints and coatings, and various polymer types and applications. Some of these projects are ongoing and may result in new uses for high-erucic-acid oils. For instance, scientists continue to research a catalytic process for cleaving erucic acid to brassylic and pelargonic acids, which may make these two products accessible to the chemical intermediates market for use in polymers, coatings, lubricants, and other functional fluids. Research on developing polymer composites from high-erucic-acid-oil derivatives also continues.

International Lubricants, Inc. (ILI), of Seattle, Washington, developed automatic transmission fluid additives based on vegetable oils, including high-erucic-acid oils. Such additives are currently used by five automobile manufacturers in Europe and are widely used in transmission repair shops in the United States and other countries. Subsequent products developed by ILI include cutting oils, hydraulic oils, power steering fluids, and, recently, a telomer that modifies the viscosity of oil-based products so they can be used in a wide range of applications. HEADE worked closely with ILI early on, and funded product testing by certified laboratories to assure product acceptance.

HEADE succeeded in promoting significant commercial production of crambe and industrial rapeseed in a relatively short time, and helped develop information about these crops, their oils, and current and potential products. The HEADE experience shows that limited Federal and state funding encouraged private sector investment and commercialization of high-erucic-acid-oil crops in the United States, and significantly expanded the body of knowledge available for future development. HEADE's multidisciplinary approach to research and development is an appropriate model for future Federal-state collaborations. It is expected that the associations and affiliations developed as the result of HEADE will continue. [Donald Van Dyne, (314) 882-0141; Irshad Ahmed, (703) 917-2060; Anton Raneses, (202) 219-0742; Alan Weber, (314) 635-3893; and Maryanne Normile, (202) 219-0774]

1. *Biodiesel Awareness and Attitudes by Transit System Managers*. Fleishman-Hillard Research, St. Louis, MO. Submitted to the National Biodiesel Board, September 1994.

2. *Biofuels: A Win-Win Strategy*. U.S. Department of Energy, Biofuels Systems Division, Washington, DC, November 1994.

Cotton Finds Markets Beyond Traditional Uses

About 90 percent of collected cotton linters and motes are transformed by chemical or mechanical means into hundreds of diverse products, while only about 5 percent of cotton lint is used in industrial applications. In 1994, an estimated supply of 10.8 billion pounds of cotton lint, linters, motes, and textile wastes were available for industrial purposes.

Cotton fibers are mechanically processed to form yarns, threads, fabrics, and absorbent products, or chemically converted to produce fiber pulp, whose cellulosic nature provides the basis for hundreds of industrial and consumer products. Some of the more traditional uses of cotton include nonwoven felts and fabrics, buffing wheels, awnings, machine belts, and upholstery fabric, linings, and padding. Moreover, the industrial market for cotton fiber has expanded into such varied applications as solid rocket propellants, oil-spill absorbents, and fingernail polishes.

Cotton Fiber Available in Various Forms

Cotton bolls are the part of the plant that hold the seed and fiber. Each boll contains four to five locks, and each lock has approximately seven seeds firmly attached to the fibers. After cotton is harvested, the ginning process separates the fiber (lint) from the cottonseed. Only very short fibers (linters) remain on the cottonseed after ginning. Linters are removed during the delinting process at cottonseed oil mills. Linters are identified as first cut, second cut, and mill run, depending upon the number of passes through the delinters. Linters, by far, are the largest source of cotton fiber for industrial applications.

Cotton ginning also can supply another source of useable fiber, gin motes. Motes are cotton fibers that are reclaimed from cotton ginning waste that accumulates during lint-cleaning operations. Reclaimed motes can be cleaned of foreign matter and sold for use in padding and upholstery filling, nonwovens, and low-quality yarns. In 1994, about 45 to 50 percent of the 1,350 U.S. cotton gins reclaimed motes for sale.

Textile-mill waste is primarily shorter or tangled fibers removed in carding and combing operations in the yarn-formation process. This material is generally very clean and can be reused by blending it back with other cotton lint to produce coarser count yarns, or used directly to form high-quality nonwovens, fine writing paper and currency paper, or in certain medical applications. For many higher value uses, it is important that mill waste be 100 percent cotton fiber and not mixed with manmade fibers.

Fiber Supplies Depend on Level of Cotton Production

The level of domestic cotton production primarily determines the quantity of the various cotton fibers available for alternative uses. While cotton-lint yields per acre can change significantly from year to year, the relative output of cottonseed and gin motes remains fairly constant per pound of cotton lint produced. The quantity of cotton linters obtained per pound of processed cottonseed also changes very little.

The 1994 cotton crop was produced on over 13.3 million harvested acres, and totaled nearly 19.7 million bales or 9.5 billion pounds of cotton lint. (The standard cotton bale weighs 480 pounds.) An average of 1,447 pounds of seed cotton must be machine picked to produce one 480-pound bale of lint (figure 5). Ginning yields approximately 800 pounds of cottonseed, and about 20 pounds of motes are available for reclaiming. Seventy-two pounds of cotton linters can be removed from the 800 pounds of seed, about 9 percent by weight. The remaining 147 pounds is trash, such as sticks, leaves, and hulls. This material is usually incinerated, composted, or plowed into fields as a soil conditioner.

Not all available motes are gathered for sale, and not all cottonseed is delinted. With about half of the U.S. cotton gins collecting motes, this would indicate a potential 1994 supply of about 197 million pounds.

Cottonseed production during marketing year 1994/95 (August-July) totaled 15.2 billion pounds. According to recent estimates, nearly 44 percent was used as animal feed (mainly for dairy cattle), seed, and other uses; 3 percent was exported as whole cottonseed; and the remaining 53 percent was crushed at oil mills. The total quantity of cotton linters is estimated at 725 million pounds (15.2 billion pounds of cot-

Figure 5
Distribution of Harvested Seed Cotton

tonseed x 53 percent crushed x 9 percent linters yield). Historically, about 20 percent of linter production is first cut, 70 percent is second cut, and the remaining 10 percent is mill run.

The supply of textile-mill or spinning waste is dependent upon the amount of cotton used by domestic mills and the type of yarn being produced. On average, a textile-processing waste factor of 7.5 percent yields an estimated supply of 407 million pounds of mill waste in 1994/95, based on the 11.3 million bales consumed.

Market Outlets Expand as Supplies Increase

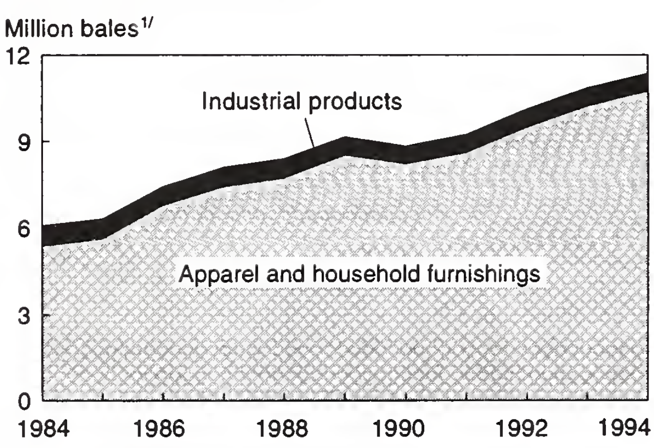
Industrial markets for cotton fiber are expected to grow in coming years as traditional markets expand and new uses are developed. Sharply increasing raw cotton production since 1986 is expanding the supply of cotton lint, linters, and motes for industrial applications. These larger supplies should improve cotton's competitive position for industrial uses compared with manmade fibers, rayon, and wood pulp.

During the past 10 years, U.S. consumption of cotton lint in all end uses has risen steadily from about 6.4 million bales in 1985 to 11.2 million in 1994 (figure 6). The use of cotton lint in industrial products, however, has remained fairly constant at about 610,000 to 680,000 bales, or 293 to 326 million pounds. Market gains in some outlets have generally been offset by losses in others.

The largest single industrial market for cotton lint is in medical supplies, accounting for 129,000 bales in 1994 and about 40 percent of all fibers used in medical applications (table 11). Together with industrial thread, tarpaulins, abrasives, and book bindings, these five markets accounted for nearly 64 percent of all industrial uses of cotton lint. In terms of fiber market share, cotton represents only about 11 percent of all fibers consumed, indicating a potential for expansion in a number of market areas.

In contrast to cotton lint, where industrial uses account for only about 5 percent of total use, approximately 90 percent of collected linters and motes end up in some form of industrial application. Through mechanical or chemical means, these fibers are transformed into hundreds of diverse products.

Figure 6
U.S. Cotton Fiber Markets



1/ A bale weighs 480 pounds.
Source: National Cotton Council of America, Memphis, TN.

According to the National Cottonseed Products Association, chemical applications account for about three-fourths of total volume (figure 7). Generally, first-cut linters are longer and whiter and are used in nonchemical markets. They usually compete with textile mill waste and lower quality cotton lint in manufacturing absorbent products, gauze, twine, wicks, and carpet yarns. A large quantity is put through a process called garnetting to produce belts and batting for use in bedding products and cushioning for furniture and automobiles.

Second-cut linters, those in largest supply, are used primarily by the chemical industry. Since linters are composed of almost pure cellulose, they represent a valuable industrial feedstock. Linters are purified by chemical treatment consisting of digesting, bleaching, and washing, and drying. The resulting linter pulp is then bulk baled, formed into long rolled sheets, or cut and packaged flat for shipment.

Further processing turns linter pulp into dissolving pulp. This pure cellulosic material is used to produce:

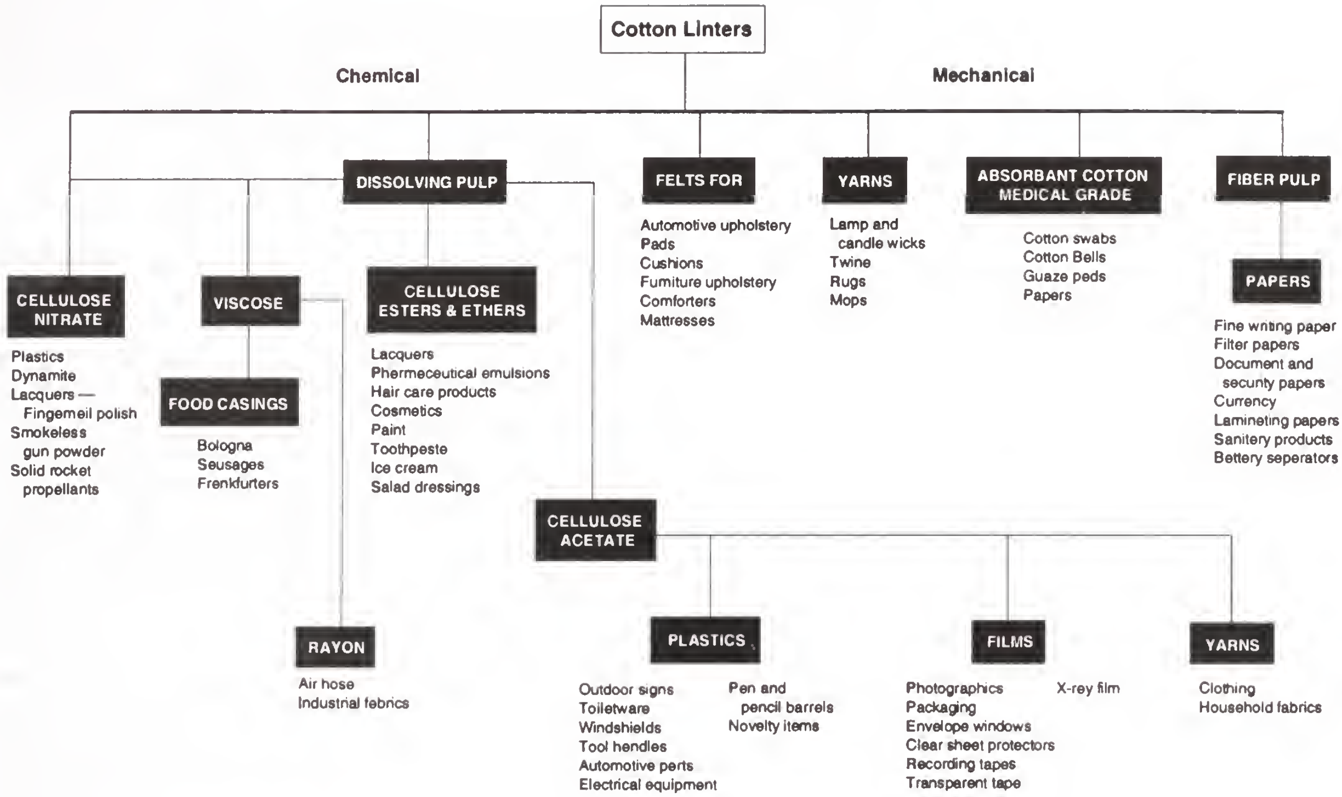
- Cellulose nitrate, the basis of many plastics, smokeless gun powder, rocket propellants, and even fingernail polish;
- Viscose, which is used extensively in food casings for bologna, sausages, and hotdogs;
- Cellulose esters and ethers, which are used in making pharmaceutical emulsions, lacquers, cosmetics, paint, and even salad dressings; and
- Cellulose acetate, a primary ingredient in producing various plastics and films, such as outdoor signs, tool handles, and automotive parts. A large quantity of cellulose acetate

Table 11--Consumption of cotton lint in major industrial markets, 1994

Product	Cotton lint consumed	Fiber market share
	1,000 bales	Percent
Medical supplies	129	40
Industrial thread	111	23
Woven tarpaulins	62	40
Woven abrasives	50	68
Book bindings	40	29
Rope, cordage, and twine	33	8
Machinery belts	23	20
Wiping and polishing cloths	23	65
Shoes and boots	20	33
Wall covering fabric	19	27
Automobile uses	16	1
Sleeping bags	14	26
Tents and trailers	14	18
Boat covers	11	17
Woven bags	11	9
All other	37	5
Total	613	11

Source: Cotton Counts Its Customers, National Cotton Council of America, Memphis, TN, June 1995.

Figure 7
Most Cotton Linters Are Chemically Processed



Source: National Cottonseed Products Association, Inc.

is used in making photographic and x-ray film, envelope windows, and recording and transparent tapes. Acetate yarns are also used in many household and industrial fabrics.

New and innovative markets continue to be developed for cotton fiber. For example, flame-retardant cotton fabric is now widely used for protective clothing in civilian and military applications, and loosely woven cotton lint and linters are being used as a planting medium to combat erosion. A recently developed linter product is an edible grade of linter fiber containing more than 99 percent total dietary fiber. This product is a pure white, flavorless, odorless flour that is chemically stable and will not react with other ingredients. It is used in many food products including baked goods, dressings, snacks, and processed meats. [Edward Glade, Jr., (202) 219-1286]

Dairy Products Used To Make Pharmaceuticals And Related Compounds

Immunized dairy cows are producing antibodies that can be used to treat gastrointestinal tract infections. Transgenic goats and cattle are being developed to produce proteins—such as antithrombin III, human-serum albumin, alpha-1 proteinase inhibitor, and human lactoferrin—used in the treatment of infections and diseases. Dairy products also are used to produce low-cost, optically pure chiral intermediates for the pharmaceutical, food, and agricultural chemical industries.

The dairy industry is expanding beyond traditional items, such as milk, cheese, butter, and ice cream, to include the production of pharmaceuticals and related high-value chemicals. Technology is now available that allows the production of antibodies and other compounds in the milk from dairy cows and other farm animals. Using animals, companies can produce significant quantities of high-value proteins at relatively low cost. These compounds are then used by the food, pharmaceutical, and chemical industries in various applications.

Significant research has been conducted by both public and private entities on using various types of animals to produce special chemicals. The following information describes products and activities under development by a few private firms.

Immunized Dairy Cows Are One Source

GalaGen Inc., a pharmaceutical company located in Arden Hills, Minnesota, immunizes pregnant cows using proprietary immunization agents and regimens. After calving, the antibody-rich colostrum is collected from the first several milkings and processed using highly refined techniques that concentrate and preserve the antibodies. The antibodies, or immunoglobulins, have the potential for both treating and preventing infections, primarily in the gastrointestinal tract. They are taken orally, either in a solid-dosage form or as a liquid reconstituted from a dry powder. Initial disease targets for GalaGen products include:

- Yeast infections of the mouth and esophagus caused by *Candida albicans*,
- Ulcers and gastritis caused by *Helicobacter pylori*,
- Antibiotic-associated diarrhea caused by *Clostridium difficile*, and
- AIDS diarrhea, caused by *Crypotosporidium parvum*.

Since the antibody products are derived from milk, they are likely to be tolerated by humans with minimal side effects. GalaGen's strategy is to first demonstrate the safety and efficacy of these products as therapeutic agents, and later to exploit the technology's value for disease prevention.

Due to the speed with which GalaGen can develop products, the relatively low cost of manufacturing, and the anticipated safety of the products, new therapeutic antibody products can be developed at a fraction of the cost of traditionally derived pharmaceuticals. GalaGen estimates that antibodies produced from dairy cows may cost as low as $1 per gram, while a similar product from cell-culture systems might cost $10,000 per gram. Also, the investment costs for cell culture could be as high as $300,000, while costs associated with a single dairy cow would be no more than a few hundred dollars annually.

GalaGen produces its antibodies through a highly efficient system that links local veterinarians, dairy farmers, and the Land O'Lakes (LOL) procurement system. LOL is a dairy marketing and input supply cooperative with 300,000 members in 15 States. LOL's procurement system meets rigorous USDA and U.S. Food and Drug Administration standards for milk quality and sanitation. Cows calve annually and produce over a pound of antibody in the first several milkings after the calf is born. With over 5,000 dairy farms in the LOL system, more than 150 tons of antibody product could be available each year.

Transgenic Animals Another Possibility

While GalaGen and other companies develop products through an immunization route, other firms are developing innovative products by developing transgenic animals. These animals are developed by physically inserting a new segment of DNA into the genes of all cells, including the reproductive cells, so that the new DNA is transmitted to offspring as a continuing trait. This is typically accomplished using test tube technologies where the DNA is micro injected into early-stage fertilized embryos. Transgenic animals were first developed in 1980-81.

Genzyme Transgenics, located in Framingham, Massachusetts, has successfully developed transgenic technology in mice and goats. Several proteins have been successfully developed and are in various stages of development, testing, and commercialization. Genzyme's Antithrombin III (AT-III), monoclonal antibodies, and other human-protein products represent a potential revenue of $300 to $400 million, according to a prospectus developed by Payne Webber in 1994.

AT-III is a blood-clotting protein usually present in human blood. Individuals lacking normal production of AT-III suffer from a high incidence of inappropriate blood clotting, especially in the lungs and extremities. It is estimated that AT-III deficiency is inherited by one in every 5,000 to 10,000 individuals. Acquired AT-III deficiency can result from illnesses—including certain liver diseases, acute venous thrombosis, septicemia (blood poisoning), and disseminated intravascular coagulation—surgical procedures, and the use of oral contraceptives.

Genzyme Transgenics established a joint venture with Sumitomo Metals in September 1990 to develop recombinant AT-III in transgenic animals. They have achieved expression levels of AT-III in the milk of transgenic mice at concentrations of more than 10 grams per liter. Transgenic goats also have been developed, with expression levels of up to 7 grams per liter in the milk. The company has produced several transgenic goats with the AT-III gene, and selected a founder goat from which their production herd is being generated. This goat has approximately 4 grams of AT-III per liter in her milk. Genzyme Transgenics expects to begin clinical studies in 1996. The company projects the worldwide market to be in excess of $300 million annually. Currently, AT-III is derived from human plasma. Payne Webber estimates that the demand for AT-III could be satisfied by about 300 transgenic goats, which would be much more economical than providing the product from increasingly expensive human plasma.

Another product developed by Genzyme Transgenics is human-serum albumin (HSA), which is a major protein component of human plasma. It is used clinically as a blood-volume expander and to increase the levels of blood protein in trauma, shock, and post-operative recovery. HSA has been expressed in transgenic mice at a level of 10 milligrams per liter of milk. The company is working on transferring HSA genes into goats in 1995.

Alpha-1 proteinase inhibitor, which is used to treat inherited alpha-1 antitrypsin deficiency, is being developed for possible use against atopic dermatitis, a chronic inflammatory skin disorder with symptoms of severe itching that is common in young children and maybe inherited. This disease affects close to 2 million Americans. Preliminary studies have shown significant clinical improvement of patients after treatment with alpha-1 proteinase inhibitor. A pilot study was initiated in March 1995 at the Boston University School of Medicine and Mount Sinai Hospital to confirm the preliminary results. Alpha-1 proteinase inhibitor has been expressed in high levels in mice and rabbits, and work has begun to develop this protein in goats.

Another company, GenPharm Europe (now GenPharm International headquartered in Mountain View, California) developed the world's first transgenic bull. Born in December 1990, GenPharm's Herman was genetically engineered to bear human genes and pass them on to his offspring. In 1994, the breeding program produced 55 bovine pregnancies, of which half were transgenic. The animals carry a gene for producing human lactoferrin (HLF) in cow's milk. Lactoferrin, an orally active protein produced naturally in human milk, has antibacterial, iron transport, and other important properties.

GenPharm plans to build a herd of several hundred transgenic cows to produce HLF on a large scale. Milk from each cow should contain several grams of HLF per liter. With each cow expected to produce up to 10,000 liters of milk per year, this would result in thousands of kilograms of HLF annually. The milk will be processed by removing water and milk fat, thus yielding milk powder containing HLF for use as an ingredient in oral formulations. The company eventually hopes to subcontract milk production to farmers or dairy cooperatives, similar to the strategy being used by GalaGen.

GenPharm intends to market HLF to populations that are at risk for bacterial infections of the gastrointestinal tract. This includes cancer patients whose immunity is lowered by chemotherapy, AIDS patients, and premature infants. Like GalaGen, GenPharm expects regulatory approval to be easier with milk products than with other genetically engineered products. The company also believes that transgenic dairy cattle are the only viable commercial route to making sufficient volumes of HLF to serve such a large market.

Chiral Compounds Made From Whey

Another company, Synthon Corporation, uses proprietary synthesis technologies to produce low-cost, optically pure chiral intermediates for the pharmaceutical, food, and agricultural chemical industries. Chiral compounds have the same chemical composition, but they have different physical geometries—they are mirror images of each other. This has implications for pharmaceutical and other industries since each form, or enantiomer, of the same drug can affect biological systems in different ways. Synthon's first product is a chiral lactone, optically pure (S)-3-hydroxy-gamma-butyrolactone, known as HGB, which is used by the pharmaceutical industry as a protein inhibitor for AIDS and a vitamin source.

Synthon has exclusive license to technologies developed at Michigan Biotechnology Institute and Michigan State University. The company uses whey and other inexpensive feedstocks, such as corn and wheat starch, to produce the chiral compounds. Synthon's production process uses water as the reaction's only solvent and processing temperatures of less than 70°C, which is safer than many conventional methods that produce chiral intermediates with toxic substances. The company has already shown that the process can be easily scaled up. They can produce 100 percent optically and chemically pure HGB, which can be sold for under $500 per kilogram. Current prices range from $1,000 to $4,000 per kilogram for a less pure product.

The 1993 worldwide market for chiral drugs was estimated at $9.2 billion for bulk active compounds and $32.4 billion for final dosage form. That represents a 16-percent increase in both categories from 1992. The worldwide market is estimated to reach $60 billion by 1997. [Donald Van Dyne, (314) 882-0141]

Industry and Residences Use Wood for Energy

The use of wood for energy is projected to reach between 2.8 and 3 quadrillion BTU's in 2000. The forest products industries themselves are the major users of wood for fuel, accounting for 69 percent of wood fuel consumed in 1992. Residential use, utilities, and other industries consume the remaining 31 percent. Production of liquid fuels from woody biomass is not economical at this time, but research is being conducted to lower costs.

USDA's Forest Service estimated wood-energy use as part of a 1993 assessment of the U.S. demand and supply of forest resources (*3*). Long-term, energy-use projections were based on various assumptions about trends in the prices of fossil and wood fuels and projected increases in energy use by various sectors such as residences, industry, and liquid fuels. Wood energy use is projected to increase from a base of 2.67 quads (quadrillion BTU's) in 1986 to about 3 quads in 2000, 3.35 quads in 2020, 3.5 in 2030, and 3.7 quads in 2040.

The U.S. Department of Energy (DOE) also has made projections for wood energy consumption, which are broken down into nonelectric and electric uses. Nonelectric uses include steam production for industry and heat for residential dwellings. Wood is the biggest supplier of renewable energy for nonelectric uses (table 12). In 1993, wood and wood waste accounted for 97 percent of nonelectric renewable energy consumption, excluding ethanol. Wood for nonelectrical uses is expected to increase from 2.09 quads in 1993 to 2.61 quads in 2010, an annual growth rate of 1.3 percent in about 17 years.

Table 12--Projected consumption of renewable energy for nonelectric uses

Energy source	1993	2000	2010	Annual growth rate 1993-2010
	Quadrillion BTU			Percent
Geothermal	0.01	0.02	0.04	7.3
Wood and wood waste	2.09	2.32	2.61	1.3
Solar thermal	0.06	0.08	0.09	2.3
Total	2.16	2.42	2.74	1.4

Source: Annual Energy Outlook, 1995, With Projections to 2010, DOE/EIA-0383(95), U.S. Department of Energy, Energy Information Administration, Washington, DC, 1995.

For electrical power generation, DOE projects wood use at approximately 0.5 quad in 2000 and about 3 quads in 2030, assuming that wood comprises more than half the energy derived from forest and agricultural residues and municipal solid waste (*2*). DOE also projects that energy crops will contribute less than 0.5 quad in 2000 but will eventually overtake agricultural and forest residues as a source of electricity before 2020. This assumption of large-scale production of short-rotation energy crops is the major difference between these DOE projections and those made by the Forest Service.

Industries Are the Biggest Users of Wood Energy

Until the turn of the 20th century, wood was the major source of energy in all sectors of the U.S. economy. But with greater popularity of low-priced coal, oil, and natural gas, use of wood fuel declined rapidly. As wood became less important as a fuel for residential heating, industrial uses of wood and wood wastes took up the slack. In 1992 (the last year for which data is available), the industrial sector accounted for 1.6 quads or 71 percent of total U.S. wood energy consumption (table 13).

The largest industrial users of wood and wood byproducts are the forest products industries themselves. In 1992, the pulp and paper industry alone used 79 percent of the wood energy consumed by the industrial sector (table 14). Black liquor (the leftover fluid from chemical pulping), wood, and bark are burned for heating, steam production, and electrical energy. Lumber mills and other primary processing industries use mill residues—such as log trimmings, sawdust, and bark—for energy. These industries are responsible for another 18 percent of industrial wood energy use. Other industries account for the remaining 3 percent.

Regional differences in wood energy use are due to the location of wood resources and wood-consuming industries. The

Table 13--U.S. consumption of wood energy by sector, 1949-92

Sector	1949	1969	1989	1990	1991	1992
	Trillion BTU					
Industrial	486	1,014	1,556	1,562	1,528	1,593
Residential	1,055	415	918	581	613	645
Electric	6	1	13	12	10	11
Total	1,529	1,430	2,487	2,155	2,150	2,249

Source: Estimates of U.S. Biomass Energy Consumption, 1992, DOE/EIA-0548(92), U.S. Department of Energy, Energy Information Administration, Washington, DC, May 1994.

Table 14--Industrial woodfuel consumption by sector and region, 1992

Sector or region	Trillion BTU	Percent of total
Sector		
Paper and allied products	1,258	79
Lumber and wood products	287	18
Other industries	48	3
Total	1,593	100
Region		
Northeast	119	7
South	1,027	64
Midwest	96	6
West	350	22
Total	1,593	100

Source: Estimates of U.S. Biomass Energy Consumption, 1992, DOE/EIA-0548(92), U.S. Department of Energy, Energy Information Administration, Washington, DC, May 1994.

South has the largest share of consumption, followed by the West, the Northeast, and the Midwest.

Areas such as New England, the upper Midwest, and parts of the South that have a surplus of low-grade hardwood trees and other biomass continue to be the focal point of biomass and biofuels energy production. For example, Weyerhaeuser Company in cooperation with Amoco Corporation, Carolina Power and Light, and Stone Webster Engineering Corporation are assessing the economic merits of expanding the use of biomass at Weyerhaeuser's New Bern, North Carolina, facility to produce both electric power and liquid fuel. Weyerhaeuser determined that a combined-cycle power system of 60 megawatts for internal use and sale has the potential for significantly increased efficiencies.

The production of electricity from wood has been highly successful in moderate-scale facilities in northern New England and the upper Midwest. In Vermont, New Hampshire, and Maine, over 700 megawatts of electrical-generating capacity have been added since 1980. About 30 cogeneration and free standing plants have been built. Many of these plants are cogeneration facilities located at pulp and paper or other forest-product mills that produce both steam and electricity. Other cogeneration facilities are located in the South, West, and Canada.

New technologies are being developed for cofiring biomass in coal-fired boilers. Dry densified wood fuels, such as pellets and brickettes, can be burned efficiently in furnace/boiler units and wood stoves by commercial or residential users. For instance, wood or biomass is pelletized and fed into coal boilers at about a 15-percent share. This low-cost supplemental fuel helps dispose of wood wastes, lower emissions of sulphur dioxide and other undesirable gases, and reduce fossil-fuel consumption. One company, Energy Performance Systems of Minneapolis, Minnesota, has developed a technology that only uses wood. It's whole-tree-energy system is designed for a 100-megawatt plant.

Residential Use Remains Despite Energy Price Changes

Until the advent of fossil fuels in the late 19th century, wood was the dominant fuel used to heat homes. Roundwood (trees from farm woodlots) remained an important but declining source of fuel through the 1940's. Residential use of wood fuel dropped 61 percent between 1949 and 1969, as farm population fell. Abundant, cheap, and convenient access to fossil fuels made wood less attractive until the energy crisis of the 1970's, when crude-oil supplies were disrupted and the delivery of natural gas curtailed. Wood's popularity grew during the 1970's and 1980's. The number of wood-burning stoves in the United States reached 14 million in 1980, up from 2.6 million in 1970 and 7.4 million in 1950.

The use of wood as a main heating source peaked during 1984-87, dipped thereafter, and leveled off. The decline in use since then has been triggered not only by lower fossil-fuel and natural-gas prices, but also by environmental concerns about using wood stoves during certain times.

Liquid Fuels From Wood a Future Possibility

The processes for making liquid fuels from wood have been known for more than a century. Considerable technological advances were achieved in Germany and Japan during World War II to compensate for lack of fossil fuels. Methanol or wood alcohol is the first and most common liquid fuel that can be produced from wood. Using a process invented by Braconnot in 1819, ethanol has been produced from wood in the United States during World War I, in Europe during World Wars I and II, and recently in the former Soviet Union. A number of other possible fuels or fuel additives can be produced from wood, including diesel fuel, methyl tertiary butyl ether, ethyl tertiary butyl ether, isopropyl alcohol, sec-butyl alcohol, tertiary butyl alcohol, and tert-amylmethyl ether.

Methanol was once derived from wood as a byproduct of charcoal manufacture, but had low yields. High-yield methanol production from wood requires producing synthesis gas, a process similar to coal gasification. Ethanol can be made using a two-stage hydrolysis process. Neither process is economically feasible at this time.

However, DOE has proposed an ambitious program, which is part of its National Energy Strategy, to produce up to 20 percent of U.S. liquid-fuel requirements from short-rotation woody plantations and other biomass. A major goal of the program is to reduce the cost of producing ethanol from energy crops from $1.27 per gallon in 1990 to less than $1 per gallon by 2005 and under 70 cents by 2010. For ethanol from cellulosic waste materials, the goals are 50 cents per gallon in 2005 and 34 cents in 2010 (*1*). This can be achieved through continued technology improvements and efficient utilization of the entire feedstock rather than just the cellulosic portion. Another goal of the program is to reduce the estimated cost of biomass-derived methanol from 93 cents per gallon in 1990 to 50 cents by 2010 using energy crops.

With practices similar to modern agriculture, plantations of high-yield, fast-growing trees could produce up to 10 tons of biomass per acre. The establishment of such plantations on

a large scale could provide a steady source of renewable fuel for cogeneration power plants to produce electricity and steam or as a raw material for chemical or alcohol production. [Thomas Marcin, (608) 231-9366, and Anton Raneses, (202) 219-0752]

1. *Biofuels: At the Crossroads, Strategic Plan for the Biofuels Systems Program.* U.S. Department of Energy, Washington, DC, July 1994.

2. *Electricity From Biomass: National Biomass Power Program Five-Year Plan (FY 1994-FY 1998).* U.S. Department of Energy, Solar Thermal and Biomass Power Division, Washington, DC, 1993, pp. 14-15.

3. Skog, Kenneth E. "Projected Wood Energy Impacts on U.S. Forest Wood Resources." *First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry.* National Renewable Energy Laboratory, Golden, CO, Vol. 10, September 1993, pp. 18-32.

Essential Oils Widely Used in Flavors and Fragrances

Essential oils and their derivatives are widely used as flavors and fragrances, a market estimated to be worth $9 billion. In 1994, the United States exported essential oils valued at $176.1 million, while importing $206.7 million. U.S. production of peppermint and spearmint oils in 1994 were 7.4 and 2.2 million pounds, respectively. Supplies of orange oil and d-limonene, which are highly dependent upon orange juice production in Brazil and the United States, could continue to be tight into 1996.

Essential oils, also called volatile or ethereal oils, refer to a large class of natural aromatic substances found in various flowers, leaves, seeds, roots, bark, wood, resin, and the rinds of some fruits. These substances resemble oils in appearance, but they are generally light, non-greasy, and highly volatile—meaning they evaporate readily. Essential oils, therefore, are chemically distinct from, and should not be confused with, fatty oils.

Essential oils are typically named after the plants from which they are derived—for example, peppermint oil and orange oil—and are called "essential" because they tend to represent the natural "essence" of the plant based on various characteristics such as odor and taste. Essential oils and their derivatives are widely used as flavors and fragrances, and some are used for their chemical or biological activity.

Essential oils are used in a wide variety of products including foods, beverages, cosmetics, pharmaceuticals, bug repellents, solvents, and more. In some cases, the oil itself may be the final product sold to consumers. It is hard to determine how many oils are commercially traded, but nearly 70 are listed in the *CTFA Cosmetic Ingredient Handbook* (*1*), and it is likely many more are sold in markets throughout the world. Production figures for most essential oils are hard to come by, but Brian M. Lawrence, a noted authority on essential oils, has estimated the world's top 20 oils by volume (table 15).

Essential Oils Face Growing Markets and Stiff Competition

Essential oils are an important component of the worldwide flavors and fragrances markets, now estimated to be worth nearly $9 billion (2). One recent study done by the Business Communications Company estimates that sales of chemicals used in finished cosmetic and toiletry products will reach $3.7 billion by 1998. Essential oils are the largest and most expensive chemical ingredients used to make these products (*3*). Two factors that are likely driving demand upward are: the "green revolution" and improving standards of living in many developing economies. The "green revolution" has many consumers in developed countries increasingly interested in products with natural ingredients, while rising standards of living and increased international trade are opening new markets for many personal-care products.

While strong worldwide flavor and fragrance markets continue to provide outlets for essential oils, market competition remains tight for many oils. While most users of essential oils are companies in Europe, the United States, and Japan, essential oil production occurs throughout the world. Though the United States is a large consumer of essential oils, U.S. production of major essential oils is limited mainly to byproducts of the citrus, wood, and pulping industries. Peppermint and spearmint are the only major oils that are produced as primary products from crops grown in the United States.

High costs of production and stiff competition from existing producers are major barriers to market entry. Production requires large amounts of raw material to yield significant quantities of oil and often requires large capital investments to process, extract, and store the oil. In addition, a new producer will often face fierce price competition from existing producers, both foreign and domestic. Some foreign countries even have special government-subsidized programs designed to promote the essential-oil industry by helping to absorb certain costs. Also, most essential oils have established buyer-seller relationships. Buyers and users of essential oils

Table 15--Essential oils: Estimated world production and value, top 20 oils

Essential oil	Volume	Value
	Tons	$1,000
Orange	26,000	58,500
Cornmint	4,300	34,400
Eucalyptus, cineole-type	3,728	29,800
Citronella	2,830	10,800
Peppermint	2,367	28,400
Lemon	2,158	21,600
Eucalyptus, citronellal-type	2,092	7,300
Clove leaf	1,915	7,700
Cedarwood (U.S.)	1,640	9,800
Litsea cubeba	1,005	17,100
Sassafras (Brazil)	1,000	4,000
Lime, distilled (Brazil)	973	7,300
Native spearmint	851	17,000
Cedarwood (Chinese)	800	3,200
Lavandin	768	6,100
Sassafras (Chinese)	750	3,000
Camphor	725	3,600
Coriander	710	49,700
Grapefruit	694	13,900
Patchouli	563	6,800

Source: Brian M. Lawrence, "A Planning Scheme to Evaluate New Aromatic Plants for the Flavor and Fragrance Industries," New Crops: Exploration, Research, and Commercialization, Jules Janick and James E. Simon, Editors, John Wiley and Sons, Inc., New York, NY, 1993, p. 620.

often have product formulas that are dependent on certain oil qualities and characteristics. Buyers, therefore, look for producers who can supply consistent and sufficient quantities of quality oils, and are reluctant to change.

Extraction Methods Vary

Chemically, essential oils are mostly tropanes, poly-isoprenoid units, aromatics, heterocyclics, and terpenes. The oils are generally located in specialized glands or cells of the plant, and can be extracted from plant material using various methods including direct steam distillation, water distillation, water and steam distillation, solvent extraction, and mechanical pressing. Other specialty methods of essential oil extraction may be used to produce some exotic and often more expensive oils. The specific method used depends upon the plant material and the desired characteristics of the end product.

Direct steam distillation or water and steam distillation are the most common extraction methods for most high-volume essential oils, such as the mint oils, eucalyptus oils, citronella, cedarwood, distilled lime, coriander, and patchouli. Prior to distillation, the plant material is often field cured, dried, and/or partially disintegrated in order to expose as many oil glands as possible to the steam. In a basic steam distillation unit, steam releases the volatile oil from the plant material, and the steam and oil then pass through a cold-water condenser to a collection container, where the volatile oil will float on top of the water and can be removed.

Most citrus oils, except distilled lime, are recovered from the fruit rinds by mechanical expression, and are largely a byproduct of the juice industry. Depending on the type of equipment, oil extraction can take place before, during, or after juice extraction. The basic cold-pressed, oil-recovery process involves rupturing (by mechanically pressing) the balloon-shaped oil glands of the peel in water. The resulting mixture is strained to remove large particles of peel and other debris, and then is centrifuged to separate the oil and water.

Solvent extraction is often used for more delicate plant materials such as flower petals, where high-temperature steam distillation would alter the chemical composition of the essential oil. The solvent chemically extracts the essential oil from the plant material, and then the solvent and the oil are separated. Various solvents can be used, but if the product is destined for human consumption in some form, alcohol (methyl or ethyl) is usually used because of possible solvent residue.

Foreign Trade Up in 1994

U.S. essential oil trade was at record-high levels for both imports and exports in 1994 (tables 16 and 17). The United States exported a total of 12.3 million kilograms of essential oils valued at $176.1 million, while importing 25.4 million kilograms worth $206.7 million. Record exports were largely attributed to gains in peppermint, spearmint, and orange oils. Record imports were due mostly to an increase in orange oil.

Mint and citrus oils (including bergamot) continue to be the most important export oils for the United States, accounting for 55 and 27 percent, respectively, of the total essential-oil export value in 1994. Major foreign markets for U.S. mint oils include the United Kingdom, Japan, and France, while major markets for U.S. citrus oils include the United Kingdom, Japan, and Canada. Citrus oils were also a significant portion of U.S. essential oil imports, accounting for 33 percent of total import value. Major foreign suppliers are Brazil, Argentina, Mexico, and Italy.

Citrus Oil Supply Dependent on Juice Production

Citrus oils are likely the most widely used essential oils in the world, with four of them—orange, lemon, lime, and grapefruit—ranking in the top 20 in volume. Most citrus oils, particularly bergamot and orange, are used as fragrance components in many cosmetic and personal-care products, such as soaps, detergents, creams, lotions, and perfumes. Orange,

Table 16--U.S. essential oil imports, volume and value, selected oils, 1992-94

Essential oil	1992 Volume	1992 Value	1993 Volume	1993 Value	1994 Volume	1994 Value
	Kilograms	$1,000	Kilograms	$1,000	Kilograms	$1,000
Peppermint	40,704	654.5	146,739	2,558.1	305,417	5,622.7
Spearmint	240,265	3,171.7	318,487	3,019.5	426,144	5,184.6
Other mint	116,015	817.6	79,498	859.6	76,858	834.9
Bergamot	42,362	3,782.5	37,821	2,362.9	37,970	1,607.6
Grapefruit	205,981	1,162.5	178,501	1,331.4	272,261	2,599.8
Lemon	1,721,645	27,898.3	1,406,479	23,028.6	1,368,513	22,918.8
Lime	1,037,955	14,406.8	756,724	13,267.9	864,563	15,175.0
Orange	9,989,360	12,272.1	11,908,627	16,205.6	14,880,881	23,525.6
Other citrus	231,612	2,430.6	358,230	2,866.6	205,115	2,863.3
Cassia	445,091	15,117.3	285,158	16,477.1	473,738	17,571.4
Cedarwood	365,855	1,276.1	338,179	1,693.6	557,895	2,977.5
Citronella	567,597	2,267.1	885,843	3,955.2	626,107	4,767.6
Geranium	53,074	1,969.5	64,251	2,924.9	82,707	4,710.2
Lavender	484,628	6,914.0	417,518	6,253.5	339,621	4,982.8
Patchouli	246,352	4,064.6	390,100	7,398.6	454,918	8,999.7
Rose	3,140	7,519.1	2,504	6,666.0	5,443	6,713.6
Sandalwood	28,716	3,152.8	31,052	3,280.9	26,398	3,669.9
Other essential oils	3,835,030	77,809.3	4,322,144	73,471.2	4,432,021	72,024.0
Total	19,655,382	186,686.4	21,927,855	187,621.2	25,436,570	206,749.0

Source: U.S. Department of Commerce, Bureau of the Census.

Table 17--U.S. essential oil exports, volume and value, selected oils, 1992-94

Essential oil	1992 Volume	1992 Value	1993 Volume	1993 Value	1994 Volume	1994 Value
	Kilograms	$1,000	Kilograms	$1,000	Kilograms	$1,000
Peppermint	1,568,728	52,613.3	1,655,168	53,278.9	2,115,696	66,925.3
Spearmint	644,246	21,254.9	700,752	22,601.6	739,792	24,207.0
Other mint	308,393	7,640.8	164,177	4,236.0	228,689	5,307.3
Bergamot	185,331	2,914.3	180,162	3,540.0	112,176	1,907.2
Lemon	868,772	10,526.7	841,422	11,834.4	818,210	11,928.2
Lime	231,407	5,052.3	196,528	4,057.5	282,917	4,607.7
Orange	3,407,916	10,195.5	3,665,228	11,965.2	4,207,009	17,142.6
Other citrus	647,530	6,272.7	727,524	10,083.0	906,093	12,532.5
Cedarwood, Clove, and Nutmeg	649,976	5,236.7	823,367	5,347.4	883,910	4,736.2
Geranium	58,786	1,565.9	18,130	671.2	39,450	977.4
Jasmine	22,813	62.4	8,603	135.2	4,739	152.5
Lavender	76,481	1,431.7	59,983	1,358.3	73,944	1,712.6
Vetiver	15,933	434.8	10,507	431.7	12,570	503.3
Other essential oils	1,546,812	21,700.7	2,164,095	24,829.8	1,899,838	23,503.4
Total	10,233,124	146,902.7	11,215,646	154,370.2	12,325,033	176,143.2

Source: U.S. Department of Commerce, Bureau of the Census.

lemon, lime, grapefruit, and to a lesser extent bergamot, are also used extensively as flavoring agents in many food products, including alcoholic and nonalcoholic beverages, frozen dairy products, candy, baked goods, gelatins and puddings, meat and meat products, and others.

In large part, the current market situation for orange oil is very dependant on juice production and markets in major producing countries, such as Brazil and the United States. Large orange juice production often translates into large oil production. Last year's drought in Brazil resulted in lower quantities of oil available from Brazil, and has led to increased prices for both U.S. and Brazilian oils.

Since the beginning of the 1994 processing crop in Brazil, spot prices for California orange oil have doubled, while Florida and Brazilian oils have more than tripled (table 52). Early indications are for a strong orange crop in Brazil this year, but early juice output forecasts are down 9 percent from last year due to expected lower juice yields and increased domestic demand for fresh oranges. In addition, last year's drought delayed bloom and fruit set for the 1995 crop, and full-scale processing did not get underway until August. U.S. juice production will not be in full swing until December 1995. If supplies of juice from Brazil are indeed lower, it could be an indication of even higher orange oil prices to come.

D-limonene Used for Adhesives

Most citrus essential oils are high in terpene content, and particularly the monoterpene hydrocarbon d-limonene, which accounts for 90 percent or more of the constituents in orange and grapefruit oils. These terpenes often are removed or reduced in order to inhibit spoilage, with the resulting oils used specifically as flavoring agents. The terpenes themselves are often a valuable commodity, and much orange oil is produced for its d-limonene content. Total production estimates for d-limonene are not available, but 19.5 million pounds were produced in Florida in 1993/94 (table 18).

Table 18--Florida d-limonene production, 1970/71-1993/94

Year	Production
	Pounds
1970/71	8,019,654
1971/72	9,456,725
1972/73	23,833,544
1973/74	21,216,553
1974/75	24,165,034
1975/76	18,472,531
1976/77	19,225,002
1977/78	17,091,624
1978/79	17,341,935
1979/80	19,629,004
1980/81	16,720,845
1981/82	13,519,036
1982/83	13,927,503
1983/84	13,721,626
1984/85	11,130,493
1985/86	12,107,458
1986/87	13,482,525
1987/88	14,563,104
1988/89	19,131,638
1989/90	15,138,111
1990/91	15,489,732
1991/92	14,493,036
1992/93	19,830,922
1993/94	19,548,481

Source: Florida Citrus Processors Association.

The largest market for both l- and d-limonene is in the production of tackifying resins for the adhesive industry, taking as much as 65 percent of limonene produced. The letters l and d are indicators of the optical activity of the limonene. For commercial use, the optical activity is of no significance except when specific taste and odor are an important factor. In this regard, it is d-limonene that must be used (along with other chemicals) to synthetically produce l-carvone, an important flavoring agent found naturally in spearmint oil. Pro-

duction of l-carvone consumes about 3 million pounds of d-limonene per year.

As with tackifying resins, optical activity is not important for the other major uses of limonene—as a solvent to replace petroleum distillates and chlorofluorocarbons (CFC's), and as an odorant for petroleum-derived solvents. With its pleasant odor and its perceived safety, limonene has found a place in many specialty cleaning products. Currently, these specialty markets account for about 25 to 30 percent of limonene consumption (*4*). Future use of d-limonene remains to be seen, but all terpenes may become increasingly important when the manufacture of CFC's and chlorinated solvents becomes illegal in the United States and 42 other countries in January 1996.

With last year's Brazilian drought and decreased quantities of orange oil, there has been a shortage of d-limonene, resulting in price increases of over 300 percent from last September (table 50). This shortage will likely continue until the Brazilian orange crop is processed. If Brazilian processing is low, d-limonene supplies could remain tight, with high prices for the remainder of the year. U.S. production will not begin until about December 1995, just as CFC phaseouts become mandatory. Many companies are already beginning to look for alternatives to CFC's, but the increasing demand and high prices for d-limonene may force some users to look for other, lower cost alternatives, such as other terpenes and synthetic cleaners. However, if supply is good and prices can be lowered when the CFC phaseout begins, d-limonene could have excellent market opportunities.

U.S. Mint Industry Centered in the West

Mint oils are among the most widely used essential oils in the world. The three main varieties of mint grown for commercial use are peppermint, spearmint, and cornmint (also called Japanese mint). Each oil is unique in its general chemical composition, and, therefore, has certain specialized uses. Both spearmint and peppermint oils are used extensively as flavoring agents in chewing gums, candies, beverages, ice creams, baked goods, oral hygiene products, and various pharmaceutical preparations. Spearmint is typically milder in flavor and fragrance, and is perhaps more widely used in products that require a milder taste or odor. Peppermint oil tends to have more antiseptic and local anesthetic qualities and, consequently, is more widely used in cold, cough, and other medicinal preparations. Cornmint oil has a very high menthol content, and is produced primarily for menthol production. Both menthol and peppermint oil are used to flavor tobacco.

Limited information on mint-oil marketing makes it difficult to asses the exact utilization of U.S. oils by various industries. However, it is likely that the traditional mint-oil products such as gums, candies, toothpastes, and mouthwashes likely account for the largest quantities of both peppermint and spear-

Table 19--U.S. peppermint oil: Supply, use, and price, 1970-94

Year	Supply			Utilization		Season-avg price	
	Production 1/	Imports 2/	Total	Exports 2/	Total	Current dollars 1/	Constant 1987 dollars 3/
	--1,000 pounds--					$/pound	
1970	5,007	5.0	5,012	1,951.0	3,061	3.68	10.48
1971	3,746	16.0	3,762	2,540.0	1,222	4.10	11.08
1972	3,004	8.0	3,012	2,227.0	785	5.25	13.49
1973	3,173	4.0	3,177	2,409.0	768	7.89	19.10
1974	3,302	7.0	3,309	2,197.0	1,112	13.80	30.73
1975	3,753	9.0	3,762	1,603.0	2,159	12.60	25.61
1976	3,700	33.0	3,733	2,194.0	1,539	14.80	28.30
1977	4,409	18.0	4,427	2,023.0	2,404	14.30	25.58
1978	5,557	6.6	5,564	2,506.7	3,057	10.60	17.58
1979	4,713	6.6	4,720	2,755.8	1,964	9.91	15.11
1980	4,611	11.0	4,622	2,206.8	2,415	9.40	13.11
1981	4,191	6.6	4,198	2,085.6	2,112	9.39	11.90
1982	3,668	6.6	3,675	2,389.8	1,285	9.24	11.03
1983	3,867	15.4	3,882	2,169.3	1,713	10.10	11.58
1984	4,334	6.6	4,341	1,880.5	2,460	10.80	11.87
1985	4,317	8.8	4,326	1,869.5	2,456	10.20	10.81
1986	4,328	101.4	4,429	2,356.7	2,073	10.70	11.04
1987	4,495	158.7	4,654	2,658.8	1,995	11.70	11.70
1988	5,360	37.5	5,397	2,709.5	2,688	15.90	15.30
1989	6,652	15.4	6,667	3,313.5	3,354	13.10	12.07
1990	6,953	34.2	6,987	3,495.7	3,492	13.90	12.27
1991	6,561	55.8	6,617	3,695.9	2,921	13.30	11.31
1992	7,383	89.7	7,473	3,458.4	4,014	12.80	10.59
1993	6,027	323.5	6,351	3,649.0	2,701	13.30	10.77
1994	7,434	673.3	8,107	4,664.3	3,443	14.60	11.56

1/ Source: USDA, National Agricultural Statistics Service. 2/ Source: U.S. Department of Commerce, Bureau of the Census. 3/ Deflated by the GDP implicit price deflator.

Table 20–U.S. spearmint oil: Supply, use, and price, 1970-94

Year	Supply			Utilization		Season-avg price	
	Production 1/	Imports 2/	Total	Exports 2/	Total	Current dollars 1/	Constant 1987 dollars 3/
	--1,000 pounds--					$/pound	
1970	2,126	--	2,126	632.0	1,494	4.64	13.22
1971	2,008	--	2,008	838.0	1,170	4.18	11.30
1972	1,511	--	1,511	842.0	669	5.14	13.21
1973	1,348	--	1,348	1,101.0	247	8.22	19.90
1974	1,455	--	1,455	982.0	473	10.70	23.83
1975	1,778	--	1,778	861.0	917	10.40	21.14
1976	1,686	--	1,686	1,167.0	519	12.30	23.52
1977	2,329	--	2,329	996.0	1,333	12.40	22.18
1978	3,244	0.0	3,244	1,040.6	2,203	7.46	12.37
1979	1,921	4.4	1,925	1,353.6	572	8.72	13.29
1980	2,139	17.6	2,157	1,183.9	973	9.61	13.40
1981	2,177	61.7	2,239	1,029.6	1,209	9.42	11.94
1982	1,355	105.8	1,461	901.7	559	12.60	15.04
1983	1,596	55.1	1,651	749.6	902	12.30	14.11
1984	2,019	163.1	2,182	857.6	1,325	12.60	13.85
1985	2,317	26.5	2,343	809.1	1,534	11.70	12.39
1986	2,658	24.3	2,682	910.5	1,772	11.40	11.76
1987	2,060	180.8	2,241	822.3	1,418	12.10	12.10
1988	1,745	152.1	1,897	985.5	912	12.80	12.32
1989	1,846	134.5	1,980	1,393.3	587	13.90	12.81
1990	2,565	327.8	2,893	1,446.6	1,446	14.90	13.15
1991	3,108	410.4	3,518	1,492.3	2,026	13.90	11.82
1992	3,640	529.7	4,170	1,420.3	2,749	12.80	10.59
1993	2,722	702.1	3,424	1,544.9	1,879	12.30	9.96
1994	2,213	939.5	3,152	1,631.0	1,522	12.30	9.74

-- = Not available.

1/ Source: USDA, National Agricultural Statistics Service. 2/ Source: U.S. Department of Commerce, Bureau of the Census. 3/ Deflated by the GDP implicit price deflator.

mint oils produced in the United States. Mint oils, particularly spearmint, also are used in various cosmetic and toiletry products. Growth in natural ingredients in these areas could mean expanded usage of mint oils as fragrances. In addition, exports traditionally have accounted for a large portion of U.S. mint oil production. During the 1990's, exports of U.S. peppermint and spearmint oil equaled 55 and 53 percent of production, respectively. Changes in U.S. mint oil production, particularly peppermint, may be highly dependent on growth in export markets.

In the United States, the mint industry is relatively small compared with most other agricultural commodity sectors. There are only about a half dozen major buyers of peppermint and spearmint oils. These buyers purchase much of the oil produced in the United States, and often contract for acreage and price prior to the growing season. Buyers are often the flavor formulators for end users, and may contract with a certain end user, such as a chewing gum manufacturer, to provide the gum company with a certain blend of oils for their product.

Because end-product manufacturers want a consistent tasting product, either they or their formula makers (buyers) seek consistent quality oils that can provide certain flavors. This often means a buyer is likely to purchase oil from certain growers that have a history of producing consistent-quality oils, despite slight changes in price. Because mint oils, like most essential oils, are very potent and usually require only small amounts in end products to produce the desired effects, the price of the oil is generally not a major component of the price of end products. For example, one pound of mint oil will flavor nearly 45,000 sticks of gum. For this reason, small to moderate changes in the price of mint oils often does not effect the purchase of these oils.

The United States is the largest producer of peppermint and spearmint oils in the world. In 1994, U.S. peppermint production was 7.4 million pounds, and spearmint production was 2.2 million pounds (tables 19 and 20). Over time, production of both peppermint and spearmint oils has shifted westward, with the Far Western States—primarily Idaho, Oregon, and Washington—accounting for 87 and 78 percent, respectively, of total U.S. production.

Spearmint oil production in the Far West has a marketing order, which has been in place since 1980. The order is a volume-control program that regulates the marketing of oil through annual sales allotments. The overall goal is to control grower stocks of oils in order to create more stable grower prices from year to year. There is no marketing order for peppermint. [Charles Plummer, (202) 219-0717]

1. *CTFA Cosmetic Ingredient Handbook.* The Cosmetic, Toiletry, and Fragrance Association, Inc., Washington, DC, 1992.

2. Layman, Patricia L. "Flavors and Fragrances Business Marked by Growth, Mergers." *Chemical and Engineering News.* American Chemical Society, Washington, DC, Vol. 72, No. 22, May 30, 1994, p. 10.

3. "Chemicals in Cosmetics and Toiletries See Modest Growth." *Chemical Marketing Reporter.* Schnell Publishing Company, New York, NY, Vol. 244, No. 10, September 6, 1993, p. 29.

4. McBride, Joseph J. "Limonene—A Versatile Chemical." *1993 Citrus Engineering Conference*, Vol. XXXIX. Florida Section of American Society of Mechanical Engineers, Lakeland, FL, 1993.

Life-Cycle Costs of Alternative Fuels: Is Biodiesel Cost Competitive for Urban Buses?

by

Nicolas B.C. Ahouissoussi and Michael E. Wetzstein [1]

Abstract: The purpose of this paper is to provide an expected cost comparison for operating a transit-bus fleet on three different alternative fuels—biodiesel, compressed natural gas (CNG), and methanol. Petroleum diesel is the base fuel. Infrastructure, refueling, and maintenance costs are all part of running an urban transit bus. Additional expenditures would be needed to change fuel storage and delivery systems, as well as bus engines and fuel systems, to use methanol or CNG.

Using a 5-percent discount rate, the present value per bus per mile was calculated for the total cost (the sum of infrastructure, bus-alteration, refueling, and maintenance expenses) of a transit fleet over the estimated 30-year life cycle of a refueling infrastructure. Not surprisingly, diesel buses had the lowest cost at 24.7 cents per mile. As biodiesel is blended with diesel, the cost per mile ranged from 27.9 to 47.5 cents, depending on the amount of biodiesel used and its estimated price. CNG's cost varied from 37.5 to 42 cents per mile, while methanol's cost was 73.6 cents per mile. This analysis indicates that, although biodiesel and biodiesel blends have higher total costs than diesel fuel, they have the potential to compete with CNG and methanol as fuels for urban transit buses.

Keywords: Diesel fuel, biodiesel, compressed natural gas, methanol, transit buses, life-cycle cost, present value.

Alternative fuels for urban mass-transit vehicles have been receiving a lot of attention lately. This interest is generated by the necessity for cleaner emissions as mandated by the Clean Air Act Amendments of 1990 (CAAA) and by concern for reliable sources of energy. Under the CAAA, the U.S. Environmental Protection Agency (EPA) established National Ambient Air Quality Standards for several pollutants: carbon monoxide, inhalable particulates, nitrogen oxides, ozone, sulfur oxides, reactive hydrocarbons, and lead. These standards for heavy-duty urban buses (table A-1) have resulted in programs to lessen emissions of these pollutants.

The CAAA and the Energy Policy Act of 1992 have opened the market for clean burning, nontoxic, biodegradable fuels. However, these laws control access to that market, requiring extensive testing and demonstrations for verifying performance and emission reductions compared with low-sulfur diesel. For example, CAAA set tighter particulate-matter controls on pre-1994-model-year urban buses in areas with a 1980 population of over 750,000. The standards become effective when engines are rebuilt or replaced after January 1, 1995.

The industry is currently looking for least-cost methods to meet the new particulate-matter standards. Promising options include retrofitting buses with emission-control equipment, such as catalytic converters and particulate traps. There is also interest in using alternative fuels that emit less particulate matter compared with petroleum diesel. However, the equipment or fuel must first be tested and certified by EPA to determine if it meets the new standards. EPA currently is reviewing alternative fuel systems for the Urban Bus Retrofit Rebuild Program.

Because of these stricter environmental regulations, the market for domestic alternative fuels is becoming more important. However, there is a gap in the literature comparing the costs of these fuels. The purpose of this paper is to provide an expected cost comparison for operating a transit-bus fleet on three different alternative fuels—biodiesel, compressed natu-

Table A-1--Emission standards for heavy duty urban bus engines

Pollutant	1991	1993	1994	1998
	Grams per horsepower hour			
Hydrocarbons	1.3	1.3	1.3	1.3
Carbon monoxide	15.5	15.5	15.5	15.5
Nitrogen oxides	5.0	5.0	5.0	4.0
Particulate matter	0.25	0.10	0.05	0.05 1/

1/ The U.S. Environmental Protection Agency may relax the particulate standard to 0.07 if 0.05 is determined not to be technologically achievable.

[1] Ahouissoussi is a research assistant, and Wetzstein is a professor, (706) 542-0758, in the Department of Agricultural and Applied Economics, University of Georgia, Athens, Georgia. Some of this research was funded by USDA's Office of Energy and New Uses under Cooperative Agreement 43-3AES-3-80153.

ral gas (CNG), and methanol. Petroleum diesel is the base fuel.

Overview of Competing Fuels

Biodiesel is a clean-burning, renewable, nontoxic, and biodegradable transportation fuel that can be used alone or in blends with petroleum-derived diesel (*2*). U.S. farmers are interested in biodiesel because advanced agricultural practices and changing dietary habits in the United States have put downward pressure on prices for vegetable oils and animal fats, the feedstocks for biodiesel. Greater dietary use of lighter, more unsaturated vegetable oils is leading to lower demand for saturated oils and fats in human and animal feeds, thus, increasing the availability of animal fats and vegetable oils for conversion into biodiesel.

From an environmental standpoint, biodiesel/diesel blends can reduce significantly emissions of particulates, carbon monoxide, and unburned hydrocarbons. For economic and engine-compatibility reasons, biodiesel often is blended with diesel at a 20/80 rate. Research results indicate that power, torque, and fuel economy with a 20-percent biodiesel blend are comparable with petroleum diesel (*3*).

Producing biodiesel is a relatively simple process. Typically, it is made by esterifying vegetable oil, such as soybean or rapeseed oil, and/or animal fat. This process involves mixing the oil or fat with an alcohol in the presence of a catalyst (potassium or sodium hydroxide) and allowing them to react. If methanol is used, the process produces a methyl ester called methyl soyate from soybean oil or methyl tallowate from animal fat. As the methyl soyate/tallowate is formed, glycerine, which can be sold as a valuable coproduct, separates out and sinks. Once degummed, the methyl soyate/tallowate is decanted off, and can be used in most diesel engines with no modification.

CNG is another fuel that can meet tighter vehicle-emission requirements. Extracted from underground reservoirs, natural gas is a fossil fuel composed primarily of methane, along with other hydrocarbons, such as ethane, propane, butane, and inert gases, such as carbon dioxide, nitrogen, and helium. Interest in using CNG as a transportation fuel has increased in recent years, particularly in urban areas because it offers the potential for reducing exhaust emissions. Also, the United States has large resources of natural gas, so this fuel could help reduce dependence on foreign oil at a competitive price.

Methanol is another alternative fuel that can be produced from domestic resources. It can be used in neat (100 percent) form as a diesel substitute or potentially blended with diesel. Very little methanol in the United States is used to fuel diesel engines. Significant amounts are used to produce methyl tertiary butyl ether (MTBE). Originally developed in the 1970's as an octane enhancer, MTBE is now blended with gasoline to help cities meet the oxygenate requirements mandated by the CAAA. The majority of the methanol made in the United States is produced from natural gas. Other sources of methanol include coal and residual oil.

Petroleum-derived diesel is used as the base fuel in this study. It is the most common fuel used in urban buses and other heavy-duty vehicles. About 25 billion gallons were consumed in the United States in 1994 for on-road use. In the past, petroleum refining was controlled primarily for gasoline yield and quality; thus, the quality of diesel fuel varied widely depending on the demand for gasoline (*1*). This has changed over the last few years. Diesel fuel now faces significant fuel-quality and engine-emissions requirements. EPA regulations set a maximum limit of 0.05 percent by weight on the sulfur content and a minimum cetane index of 40 for diesel fuel used in on-road vehicles.

Bus Refueling Facilities

Most urban transit authorities operate refueling facilities for their buses. Often at a central location, these facilities are devoted exclusively to refueling buses and house sheltered chassis lanes with eight to ten doors, fueling pumps, storage tanks, maintenance equipment, and emergency fire equipment. A chassis lane is a driveway next to the refueling pump. In a lane, maintenance equipment is used to clean one bus while another one is being fueled. The regional transport district refueling station in Denver, Colorado, which was used to gather the data for this analysis, refuels approximately 280 buses per night in a three-lane system. The three lanes can service 360 buses at full capacity. Diesel fuel is stored in underground tanks, with a capacity of 20,000 gallons each.

No infrastructure changes or engine modifications are needed for using biodiesel. Only the fuel is modified by blending diesel fuel with biodiesel. In this analysis, fuels using 20, 35, 60, and 100 percent (neat) biodiesel were considered. However, the level of BTU's associated with biodiesel-blended fuels is lower than with diesel, which results in a lower level of fuel efficiency. The Colorado Institute for Fuels and High-Altitude Engine Research has estimated the fuel efficiency of biodiesel blends compared with diesel at 99.16, 97.66, 92.97, and 88.87 percent for 20, 35, 60, and 100 percent biodiesel, respectively.

To handle methanol or CNG, a diesel refueling station would need to be modified. For methanol, alcohol-compatible fuel tanks, new dispensers, and safety equipment would need to be added. Also, additional fuel storage capacity would be necessary because methanol buses require, on average, 2.5 times as much fuel as diesel buses. To service dual CNG/diesel buses, additional equipment to handle CNG would be necessary, including gas supply equipment, compressors, control valves, piping, gas conditioners, dispensers, and safety equipment. The compressors condense the gas to 3,000 pounds per square inch. Also, a CNG fuel system would need eight lanes instead of three to service the same number of buses. It takes longer to refuel with CNG because the refueling rate slows as the tank fills and the pressure increases.

In addition to new facilities, the buses themselves would have to be modified to use methanol or CNG. To run on methanol, buses would need a new engine and fuel system. CNG buses would use a modified diesel engine with a new fuel system.

Cost Analysis Procedures and Data

The economic performance of alternative fuels for urban transit buses can be measured by estimating and comparing the expected total cost of running a bus fleet during its anticipated operating life using different fuels. The comparison of total costs is enhanced by considering the present value of total fleet costs over the fleet's life cycle. Present value explicitly incorporates the time value of money by comparing the costs in one time period, say a given month, with the costs in another period. The time value of money assumes that a dollar forthcoming a year from now is not worth as much as a dollar today. Thus, future costs are reduced by a discount rate so they are comparable with current costs. The present value of costs is then the sum of all discounted costs over the total number of years a fleet is in operation by a transit authority.

Infrastructure, refueling, and maintenance costs are all part of running a bus. Infrastructure costs represent lane building and tankage installation expenditures. Changing fuel storage and delivery systems, as well as bus engines and fuel systems, to use methanol or CNG will require additional expenditures. Refueling costs include actual fuel expenditures and refueling labor charges. Maintenance expenses include repair, rebuild, and insurance costs, and costs associated with the loss of ridership and good will due to unexpected breakdowns.

Generally, the purchase prices for engines that run on diesel, biodiesel, CNG, and methanol are comparable. However, engine-rebuild and fuel-system costs differ by fuel type and the number of miles between rebuilds. Calculating engine-rebuild costs for alternatively fueled buses is at present a tricky proposition. The date when an engine was rebuilt and monthly mileage since the last rebuild are key bits of information. Unfortunately, data on monthly mileage and time of rebuilds for alternatively fueled buses are still quite limited.

Most experiments on alternative fuels have been mainly for demonstration purposes, resulting in short duration times and little, if any, collected data. One exception was an experiment by the Denver, Colorado, regional transportation district. As part of its commitment to meet Clean Air regulations, the district has conducted research on alternative fuels using transit buses. The experiment, which lasted from June 1989 to December 1993, used five diesel buses, which could use both diesel and biodiesel fuel, and five methanol buses (table A-2). Five dual CNG/diesel buses, which are diesel buses converted so they can also use CNG, were added in 1991.

The three fleets of buses were exposed to similar operating conditions such as scheduled speeds, stops per mile, traffic conditions, and passenger loading. They were also maintained under the same preventive maintenance program. This unique data set allows a cost comparison of alternative fuels based not only on fuel cost and usage, but also on maintenance, repair, engine-rebuild, and in-service failure costs for the total operational life of the transit buses.

In this experiment, the variation of mileage at rebuild was large, particularly for diesel and methanol buses. This indicates that rebuild decisions are based upon other information besides the odometer value. CNG/diesel buses were rebuilt in approximately half the time and mileage of diesel and methanol buses, which resulted in higher maintenance costs. However, these higher costs are potentially offset by the CNG/diesel buses' considerably lower standard deviation. A lower standard deviation implies less uncertainty regarding timing of rebuilds and, thus, possibly lower costs in terms of less unexpected rebuilds.

The transportation district's data suggest that a set time frame or mileage may not be a good indicator for when engines need to be rebuilt. In this case, Rust proposes taking observed engine rebuilds as optimal and infer the total maintenance costs leading to these rebuilds (*4*). Basically, this method assumes that transit authorities have developed a procedure

Table A-2--Experiment statistics

Item	Diesel	Methanol	CNG/Diesel
Number of Buses	5	5	5
Bus characteristics			
Engine	6V-92 TA DDEC I	6V-92 TAM DDEC II	6V-92 TA DDECII
Transmission	Allison HTB-748 ATEC	Allison V-731 ATEC	Allison HTB-748 ATEC
Purchase price (1991 model)	$217,400	$188,500	$252,400
Gross weight (pounds)	35,130	34,970	38,000
Fuel tank (gallons)	125	285	1/
Mileage at rebuild			
Maximum	89,600	110,100	34,500
Minimum	12,150	14,590	20,200
Mean	55,271	53,432	26,833
Standard deviation	28,861	27,016	5,901
Elapsed time between rebuilds		Months	
Maximum	28	34	10
Minimum	3	5	6
Mean	17.57	17.33	8.33
Standard deviation	9.93	8.79	1.63

1/ 8,084 cubic feet of compressed natural gas (CNG) and 62.5 gallons of diesel.

Source: The Denver, Colorado, regional transportation district.

for optimally determining when a bus should be rebuilt. A computer program developed by Rust was used in this analysis to calculate engine-rebuild and monthly maintenance costs. Actual rebuild expenses were used for scaling these parameters and estimating maintenance costs.

Comparing Life Cycle Costs

The Denver transportation district scaled up their data to estimate the costs for running a fleet of 300 buses on diesel, biodiesel, methanol, and CNG. The costs of alternatively fueled buses are based on the assumption that regional transportation districts already have diesel-bus refueling facilities. Therefore, the fixed costs for alternative-fuel facilities are incremental to diesel-facility fixed costs. This assumption may favor diesel and biodiesel, but it is realistic given current transit operations.

Total infrastructure cost per bus is only $1,461 for diesel and biodiesel (tables A-3 and A-4) compared with about $10,000 per bus for methanol and CNG/diesel buses (tables A-5 and A-6). Not only are six more storage tanks needed for methanol, they are approximately 6.5 times more expensive than diesel storage tanks. The infrastructure for CNG/diesel buses also are significantly more expensive than diesel due to the requirement of eight fueling lanes instead of three and storing pressurized fuel. In addition, the cost to change a bus so it will run on methanol instead of diesel is $29,900 and the cost of altering a diesel bus to use CNG is $35,000. In this analysis, these expenses accrue every 10 years for replacing the engine and fuel system.

In addition to infrastructure and bus expenses, transit operators also face refueling and maintenance costs. Refueling labor costs are based on one supervisor and three laborers per lane. Two laborers drive the buses to the lane and a third laborer refuels the buses. The hourly wage rate for supervisors and laborers is $16.00 and $13.95, respectively. Adding in benefits of 29 percent, 15 days of paid vacation, and 8 days of paid sick leave results in actual wage rates of $22.89 per hour for supervisors and $19.95 for laborers.

The wholesale, pretax price of diesel used in the study was 67 cents per gallon, and the price for methanol was 59 cents per gallon. Given the current thin market for biodiesel, the long-run equilibrium price has yet to be determined. Therefore, three prices for biodiesel were used: $1.75, $2.50, and $3.00 per gallon. The $2.50 per gallon represents the average price of biodiesel. The $1.75 represents an optimistic near-term scenario and assumes that some lower cost feedstocks are used, while the $3 price reflects higher production costs.

Three prices for CNG also were considered: 14.06, 28.12, and 42.18 cents per equivalent gallon. These prices are associated with $1, $2, and $3, respectively, per 1 million BTU's of CNG. (An equivalent gallon is the number of BTU's in a gallon of diesel fuel. One million BTU's of CNG divided by 140,600 BTU's per gallon of low-sulfur diesel yields 7.1123 equivalent gallons of CNG.) The price of natural gas is set by local utilities and approved by state public utility commissions. Thus, fleet operators around the country face different prices for CNG.

Annual refueling costs are $21,102 per bus for methanol buses, which is about twice the refueling cost for diesel buses. The 2.5-times higher fuel consumption for methanol buses requires 4.5 times more labor for refueling. The additional labor needed for the extra five refueling lanes for CNG/diesel buses account for most of its 37 percent higher annual refueling cost per bus compared with diesel buses. Conversely, most of the additional cost for biodiesel was for the fuel itself, 73 percent of the $14,795 annual refueling costs.

Major maintenance costs involve engine rebuilds and general bus maintenance and repair. Rebuild costs are $6,500 per engine for diesel, biodiesel, and CNG/diesel and $9,500 for methanol buses. In this analysis, rebuilds were estimated to occur every 20, 21, and 10 months for diesel and biodiesel, methanol, and CNG, respectively. These rebuild cycles were derived by dividing average mileage at rebuild by monthly travelled mileage.

Given monthly mileage and considering marginal maintenance cost changes every 5,000 miles, maintenance cost estimates are used in calculating average monthly maintenance costs over a rebuild cycle, which are then used to calculate the present value of total costs. Because regional transportation districts expect average monthly maintenance costs to rise over time, they were increased every 5,000 miles in this analysis. The estimated maintenance cost per month, based on Rust's model, for diesel and biodiesel, $4.34, is quite low compared with the cost for methanol of $31.84 (table A-7). However, this marginal maintenance cost per month is higher than the $1.80 cost for CNG/diesel.

Present value per bus per mile was calculated for the total cost (the sum of infrastructure, bus-alteration, refueling, and maintenance expenses) of a transit fleet over the estimated 30-year life cycle of the refueling infrastructure. Considering a 5-percent discount rate, it is not surprising that diesel buses result in the lowest per-mile cost, 24.7 cents (table A-8). Diesel and biodiesel buses have the lowest infrastructure cost per bus compared with methanol and CNG/diesel buses. Also, diesel and biodiesel buses do not incur the added cost of engine and fuel-system conversion required every 10 years. Another reason for this relatively low cost per mile for diesel is that the estimated increase in maintenance costs per month is quite low compared with the maintenance costs for methanol.

As biodiesel is blended with diesel, the cost per mile ranges from 27.9 cents to 47.5 cents, depending on the amount of biodiesel used and its price. The present value of using neat biodiesel ranges from 43.8 cents per mile to 64.5 cents. Although this is 1.8- to 2.6-times higher than diesel's 24.7 cents, it is still lower than methanol's cost of 73.6 cents per mile. However, methanol blended with diesel should have cost reductions similar to biodiesel blends, making it potentially

Table A-3--Estimated infrastructure and refueling costs for a fleet of 300 diesel buses

Item	Unit cost	Units	Total cost
Infrastructure cost per lane 1/			
Building cost 2/	$92,000 per lane	3	$276,000
Tankage 3/	$40,600 per tank	4	162,400
Total			438,400
Infrastructure cost per bus		300	1,461
Refueling labor costs per lane per day 4/			
Supervisor 5/	$22.89 per hour	1/3	61
Labor 6/	$19.95 per hour	3	479
Total			540
Annual refueling labor costs 7/	$3,240 per day	365	1,182,600
Annual refueling costs per bus			
Labor costs		300	3,942
Fuel usage 8/	67 cents per gallon	10,392	6,963
Total			10,905
Annual cost per mile 9/			0.298

1/ Three lanes can service 360 buses at full capacity. The District refuels approximately 280 buses per night in a three-lane system. 2/ $1,000 per square foot. Service life for the building is 30 years. 3/ A tank capacity of 26,666 gallons is required per lane. Four FTP-3 fuel tanks, with a capacity of 20,000 gallons each, were used to meet this requirement. Material and installation costs equal $40,600 per tank. 4/ Refueling labor includes one supervisor per three lanes and three laborers for each lane. Two laborers drive the buses to the lane and a third laborer refuels the buses. 5/ The wage rate for supervisors is $16.00 per hour, plus benefits of 29 percent. A 40-hour work week equals 2,080 hours per year. Subtracting 15 days of paid vacation, 9 paid holidays, and 8 paid sick-leave days yields 1,824 hours per year. Therefore, the actual hourly rate is $16.00[(2,080/1,824) + 0.29] = $22.89. 6/ The same formula yields an actual wage rate of $19.95 per hour for laborers based on an hourly rate of $13.95. 7/ Three lanes at $540 per lane times an overhead multiplier of two equals $3,240. 8/ With buses using an average of 866 gallons per month. 9/ With 36,578 miles driven per bus per year.
Source: The Denver, Colorado, regional transportation district.

Table A-4--Estimated infrastructure and refueling costs for a fleet of 300 buses running on a 20-percent biodiesel blend

Item	Unit cost	Units	Total cost
Infrastructure cost per lane 1/			
Building cost 2/	$92,000 per lane	3	$276,000
Tankage 3/	$40,600 per tank	4	162,400
Total			438,400
Infrastructure cost per bus		300	1,461
Refueling labor costs per lane per day 4/			
Supervisor 5/	$22.89 per hour	1/3	61
Labor 6/	$19.95 per hour	3	479
Total			540
Annual refueling labor costs 7/	$3,240 per day	365	1,182,600
Annual refueling costs per bus			
Labor costs		300	3,942
Fuel usage 8/	$1.036 per gallon	10,476	10,853
Total			14,795
Annual cost per mile 9/			0.404

1/ Three lanes can service 360 buses at full capacity. The District refuels approximately 280 buses per night in a three-lane system. 2/ $1,000 per square foot. Service life for the building is 30 years. 3/ A tank capacity of 26,666 gallons is required per lane. Four FTP-3 fuel tanks, with a capacity of 20,000 gallons each, were used to meet this requirement. Material and installation costs equal $40,600 per tank. 4/ Refueling labor includes one supervisor per three lanes and three laborers for each lane. Two laborers drive the buses to the lane and a third laborer refuels the buses. 5/ The wage rate for supervisors is $16.00 per hour, plus benefits of 29 percent. A 40-hour work week equals 2,080 hours per year. Subtracting 15 days of paid vacation, 9 paid holidays, and 8 paid sick-leave days yields 1,824 hours per year. Therefore, the actual hourly rate is $16.00[(2,080/1,824) + 0.29] = $22.89. 6/ The same formula yields an actual wage rate of $19.95 per hour for laborers based on an hourly rate of $13.95. 7/ Three lanes at $540 per lane times an overhead multiplier of two equals $3,240. 8/ With buses using an average of 873 gallons per month. The fuel is a 20-percent biodiesel blend, with biodiesel at $2.50 per gallon. 9/ With 36,578 miles driven per bus per year.
Source: The Denver, Colorado, regional transportation district.

Table A-5--Estimated infrastructure and refueling costs for a fleet of 300 methanol buses

Item	Unit cost	Units	Total cost
Infrastructure cost per lane 1/			
Building cost 2/	$92,000 per lane	3	$276,000
Tankage 3/	$268,148 per tank	10	2,681,480
Total			2,957,480
Infrastructure cost per bus		300	9,858
Fuel alteration costs per bus 4/			29,900
Refueling labor costs per lane per day 5/			
Supervisor 6/	$22.89 per hour	1/3	61
Labor 7/	$19.95 per hour	7.5	1,197
Total			1,258
Annual refueling labor costs 8/	$7,550 per day	365	2,755,546
Annual refueling costs per bus			
Labor costs		300	9,185
Fuel usage	59 cents per gallon	19,867	11,722
Lubrizol 9/	$15.69 per gallon	12.42	195
Total			21,102
Annual cost per mile 10/			0.708

1/ Three lanes can service 360 buses at full capacity The District refuels approximately 280 buses per night in a three-lane system. 2/ $1,000 per square foot. Service life for the building is 30 years. 3/ Ten fuel tanks are required instead of four because methanol buses use, on average, 2.5 times more fuel. 4/ The additional cost per bus for a methanol engine and fuel system. 5/ Refueling labor includes one supervisor per three lanes and 7.5 laborers for each lane. Since 2.5 times more fuel is used, it is assumed that 2.5 times more labor is needed to refuel the buses. 6/ The wage rate for supervisors is $16.00 per hour, plus benefits of 29 percent. A 40-hour work week equals 2,080 hours per year. Subtracting 15 days of paid vacation, 9 paid holidays, and 8 paid sick-leave days yields 1,824 hours per year. Therefore, the actual hourly rate is $16.00[(2,080/1,824) + 0.29] = $22.89. 7/ The same formula yields an actual wage rate of $19.95 per hour for laborers based on an hourly rate of $13.95. 8/ Three lanes at $1,258.24 per lane times an overhead multiplier of two equals $7,550. 9/ Lubrizol is added at 6.25 gallons per 10,000 gallons of methanol. 10/ With 29,801 miles driven per bus per year.
Source: The Denver, Colorado, regional transportation district.

Table A-6--Estimated infrastructure and refueling costs for a fleet of 300 Dual CNG/diesel buses

Item	Unit cost	Units	Total cost
Infrastructure cost per lane 1/			
Building cost 2/	$92,000 per lane	8	$736,000
Fueling facility 3/			2,320,500
Total			3,056,500
Infrastructure cost per bus		300	10,188
Fuel alteration costs per bus 4/			35,000
Refueling labor costs per lane per day 5/			
Supervisor 6/	$22.89 per hour	1/8	23
Labor 7/	$19.95 per hour	3	479
Total			502
Annual refueling labor costs 8/	$8,028 per day	365	2,930,337
Annual refueling costs per bus			
Labor costs		300	9,768
Fuel usage 9/	40 cents per gallon	10,764	4,306
Maintenance costs			400
Compressor energy costs	$1.28 per day	365	467
Total			14,941
Annual cost per mile 10/			0.431

1/ Eight lanes can service 300 buses. 2/ $1,000 per square foot. Service life for the building is 30 years. 3/ Estimated installation costs are $1.7 million; plus 10 percent for contractor's markup; 10 percent for engineering; 5 percent for development and permitting; and 10 percent of the $1.7 million, engineering, development, and permitting costs for contingency. 4/ The additional cost per bus for a compressed natural gas (CNG) engine and fuel system. 5/ Refueling labor includes one supervisor per eight lanes and three laborers for each lane. 6/ The wage rate for supervisors is $16.00 per hour, plus benefits of 29 percent. A 40-hour work week equals 2,080 hours per year. Subtracting 15 days of paid vacation, 9 paid holidays, and 8 paid sick-leave days yields 1,824 hours per year. Therefore, the actual hourly rate is $16.00[(2,080/1,824) + 0.29] = $22.89. 7/ The same formula yields an actual wage rate of $19.95 per hour for laborers based on an hourly rate of $13.95. 8/ Eight lanes at $501.77 per lane times an overhead multiplier of two equals $8,028. 9/ Equivalent gallons. 10/ With 34,691 miles driven per bus per year.
Source. The Denver, Colorado, regional transportation district.

competitive with the other alternative fuels. CNG/diesel has a significantly lower cost per mile compared with methanol, but it is still approximately 1.7 times more expensive than diesel. Twenty-and 30-percent biodiesel blends, at all price levels, are competitive with CNG/diesel at the lowest price for CNG. Assuming these blends can comply with regulatory emission standards, biodiesel fuels at prices as high as $3.00 per gallon could compete with the other alternative fuels.

Table A-7--Estimated maintenance costs for diesel, biodiesel, methanol, and CNG/diesel buses

Summary statistics	Diesel and biodiesel	Methanol	CNG/diesel
Rebuild costs	$6,500	$9,500	$6,500
Structural coefficients			
Rebuild cost coefficient	5.06	4.64	3.21
Operating cost coefficient 1/	3.38	15.55	0.89
Scale parameter 2/	1,284	2,047	2,025
Maintenance costs per 5,000 miles 3/	$4.34	$31.84	$1.80

1/ Operating costs include repair and insurance costs and loss of ridership and goodwill costs due to unexpected breakdowns. 2/ The scale parameter is the actual rebuild cost divided by the rebuild cost coefficient. 3/ Estimated maintenance costs are obtained by multiplying the scaling parameter times the operating cost coefficient and dividing by 1,000.

Table A-8--Present value per mile of total cost of running a bus over a 30-year life cycle, with an annual discount rate of 5 percent

Fuel	Total cost
	Cents per mile
Diesel	24.7
Methanol	73.6
CNG/Diesel at	
$0.1406 per gallon	37.5
$0.2812 per gallon	39.8
$0.4218 per gallon	42.0
Biodiesel at $1.75 per gallon	
20 percent blend	27.9
35 percent blend	30.6
60 percent blend	35.7
100 percent	43.8
Biodiesel at $2.50 per gallon	
20 percent blend	30.2
35 percent blend	34.6
60 percent blend	42.8
100 percent	56.3
Biodiesel at $3.00 per gallon	
20 percent blend	31.6
35 percent blend	37.2
60 percent blend	47.5
100 percent	64.5

This analysis indicates that, although biodiesel and biodiesel blends have higher total costs than diesel fuel, they have the potential to compete with CNG and methanol fuels (figure A-1). As provisions of the Clean Air Act and the Energy Policy Act are implemented, and concerns about the impact of fossil fuels on the environment and health solidify, the market for alternative fuels is likely to grow. Based on this present-value analysis of total life-cycle costs, biodiesel seems well positioned to compete with other alternative fuels in the transit-bus market.

Acknowledgements

This research was partially funded by USDA's Office of Energy and New Uses and the National Biodiesel Board, Jefferson City, Missouri.

References

1. *Biodiesel Alert.* National Biodiesel Board, Jefferson City, MO, 1993, 1994, 1995, selected issues.

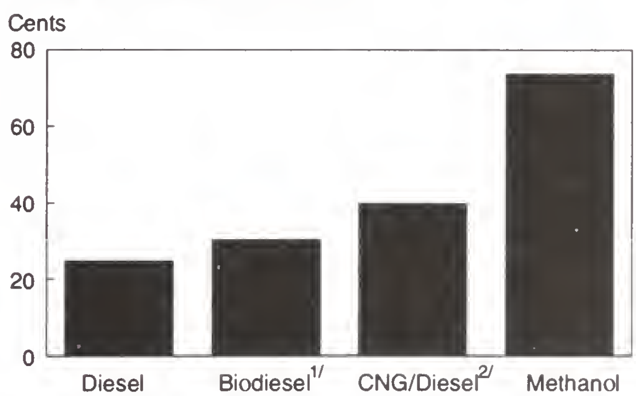
2. Holmberg, W.C., E.E. Gavett, and P.N. Merrill. *National SoyDiesel Development Board Standards for Biodiesel.* American Biofuels Association, Washington DC, 1993.

3. Howell, S.A. and A. Weber. "U.S. Biodiesel Overview." *Proceedings, Second Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry,* August 21-24, 1995, Portland, OR, pp. 840-848.

4. Rust, J. "Optimal Replacement of GMC Bus Engines: An Empirical Model of Harold Zurcher." *Econometrica,* Vol. 55, 1987, pp. 999-1033.

Figure A-1

Present Value of Total Costs Per Bus Per Mile for Diesel and Alternative Fuels



1/ A 20-percent blend, with biodiesel at $2.50 per gallon. 2/ With CNG (compressed natural gas) at 28.12 cents per gallon.

List of Tables

Tables | Page

Special article tables

Table 21--Farm value of processed farm commodities purchased by various industries, 1987 1/

Sector	Construction	Clothing	Paper and printing	Chemical	Durable goods
			Million Dollars		
Livestock 2/		274.80		100.90	1.80
Cotton		3,256.10			
Field crops 3/	100.00				
Other crops 4/	140.50			113.60	20.00
Meat processor 5/		546.88		29.70	78.63
Livestock		546.72		29.69	78.61
Field crops		0.16		0.01	0.02
Other crops				6/	6/
Prepared feed				0.92	
Livestock				0.04	
Cotton				0.03	
Field crops				0.86	
Other crops				0.01	
Corn milling			138.43	68.00	6.70
Field crops			138.03	67.81	6.70
Other crops			0.39	0.19	
Distilled liquor 7/		0.19	0.38	0.23	1.75
Livestock			6/		0.01
Field crops		0.19	0.38	0.23	1.74
Other crops			6/		6/
Cottonseed oil			24.35	3.30	7.63
Cotton			24.35	3.30	7.63
Soy milling				95.66	
Field crops				94.92	
Other crops				0.73	
Other vegetable oil				67.45	1.21
Cotton				21.12	0.38
Field crops				46.33	0.83
Other crops				6/	6/
Animal fats		0.24		7.95	
Livestock		0.24		7.95	
Field crops				6/	
Shortening, table oil, and margarine				72.08	
Livestock				5.74	
Cotton				4.64	
Field crops				61.28	
Other crops				0.42	
Other processed foods				1.76	0.08
Livestock				0.01	6/
Cotton				1.71	0.08
Field crops				0.04	6/

1/ The farm value is reported by commodity and processing sector for various industries purchasing processed agricultural commodities. Totals may not add due to rounding. 2/ Dairy, poultry, and meat animals. 3/ Food grains, feed grains, tobacco, fruit, tree nuts, vegetables, sugar, and oilseed crops. 4/ Miscellaneous crops and greenhouse and nursery products. 5/ Meat packing plants, sausages, and poultry. 6/ Less than $10,000. 7/ Excluding wine and beer.

Sources: Kenneth Hanson, ERS; Benchmark Input-Output Accounts of the United States, 1987, Department of Commerce, Bureau of Economic Analysis, November 1994; and Survey of Current Business, Vol. 5, No. 4, April 1994.

Table 22--Flaxseed: Acreage planted, harvested, yield, production, and value, United States, 1986-95

Year	Planted	Harvested	Yield	Production	Value
			Bushels	1,000	
	---1,000 acres---		per acre	bushels	$1,000
1986	720	683	16.9	11,538	39,962
1987	470	463	16.1	7,444	25,188
1988	275	226	7.1	1,615	12,200
1989	195	163	7.5	1,215	8,724
1990	260	253	15.1	3,812	21,108
1991	356	342	18.1	6,200	21,845
1992	171	165	19.9	3,288	13,543
1993	206	191	18.2	3,480	14,467
1994 1/	178	171	17.1	2,922	13,655
1995 2/	213	206	18.0	3,710	N.A.

N.A. = Not available.
1/ Preliminary. 2/ Forecast.

Table 23--Linseed oil, supply and disappearance, United States, 1986/87-1995/96

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Total	Disappearance: Exports	Disappearance: Domestic	Disappearance: Total	Ending stocks
	--Million pounds--						
1986/87	39	201	240	6	183	189	51
1987/88	51	217	268	8	219	227	41
1988/89	41	170	211	12	151	163	48
1989/90	48	165	213	12	164	176	37
1990/91	37	176	213	6	167	173	40
1991/92	40	182	222	12	170	182	40
1992/93	40	172	212	8	150	158	54
1993/94	54	176	228	3	162	165	63
1994/95 1/	63	171	237	24	168	192	45
1995/96 2/	45	177	223	8	170	178	45

1/ Preliminary. 2/ Forecast.

Table 24--Linseed meal, supply and disappearance, United States, 1986/87-1995/96

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Imports	Supply: Total	Disappearance: Exports	Disappearance: Domestic	Disappearance: Total	Ending stocks
	--1,000 short tons--							
1986/87	5	185	2	192	63	127	190	2
1987/88	2	198	2	202	59	140	199	3
1988/89	3	156	11	170	63	102	165	5
1989/90	5	153	9	167	23	139	162	5
1990/91	5	162	3	170	41	124	165	5
1991/92	5	167	0	172	40	127	167	5
1992/93	5	159	2	166	55	106	161	5
1993/94	5	160	2	167	49	113	162	5
1994/95 1/	5	158	5	168	58	105	163	5
1995/96 2/	5	162	3	170	50	115	165	5

1/ Preliminary. 2/ Forecast.

Table 25--Rapeseed: Acreage planted, harvested, yield, production, and value, United States, 1987-94

Year	Planted	Harvested	Yield	Production	Value
			Bushels	1,000	
	---1,000 acres---		per acre	bushels	$1,000
1987	20.0	19.4	22.7	21,981	N.A.
1988	13.5	13.1	24.1	15,822	N.A.
1989	14.0	13.6	28.2	19,143	2.01
1990	15.0	14.5	31.2	22,717	2.33
1991	18.2	15.6	20.7	16,146	1.63
1992	9.6	7.7	24.5	9,408	0.09
1993 1/	15.0	12.0	24.6	14,760	1.31
1994 2/	16.0	12.8	24.7	15,808	1.40

N.A. = Not available.
1/ Preliminary. 2/ Forecast.

Table 26--Total fats and oils consumption, with inedible by category, United States, 1987/88-94

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1987/88	20,241.2	14,175.5	6,065.7	868.6	179.1	1,967.6	196.3	107.8	2,203.8	542.8
1988/89	19,426.7	13,542.0	5,884.7	744.5	180.3	2,079.3	202.3	115.8	2,074.1	488.4
1989/90	20,036.0	14,382.7	5,653.3	792.0	89.5	2,143.5	222.4	157.1	1,944.7	304.1
1991	20,332.1	14,613.0	5,719.1	832.9	106.8	1,974.0	182.6	101.7	2,234.7	286.4
1992	20,751.7	14,847.3	5,904.4	738.8	123.8	2,176.5	165.5	109.4	2,041.2	549.3
1993	21,590.4	15,744.7	5,845.7	748.5	125.2	2,199.5	170.2	116.0	1,897.6	588.7
1994	22,058.7	15,373.8	6,684.9	770.0	1,151.1	2,272.5	240.7	219.3	2,306.2	761.1

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Department of Commerce, Bureau of the Census.

Table 27--Castor oil consumption, with inedible by category, United States, 1987/88-94

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1987/88	74.6	0.0	74.6	d	4.3	0.0	4.8	6.1	d	59.0
1988/89	59.2	0.0	59.2	d	4.8	0.0	4.5	6.2	0.0	43.2
1989/90	51.4	0.0	51.4	d	5.9	0.0	4.0	5.7	0.0	d
1991	46.0	0.0	46.0	d	5.9	0.0	4.0	d	0.0	31.7
1992	41.3	0.0	41.3	d	d	0.0	3.3	3.5	0.0	28.4
1993	54.2	0.0	54.2	d	d	0.0	3.5	2.8	0.0	37.8
1994	61.9	0.0	61.9	d	d	0.0	1.9	2.4	0.0	41.0

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Department of Commerce, Bureau of the Census.

Table 28--Coconut oil consumption, with inedible by category, United States, 1987/88-94

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1987/88	788.6	233.4	555.4	213.8	d	0.0	7.2	d	131.4	d
1988/89	688.8	211.2	477.6	130.6	1.4	d	14.6	d	121.9	206.6
1989/90	525.2	160.6	364.6	156.9	2.1	0.0	9.7	4.0	134.6	57.3
1991	815.6	153.0	662.6	158.0	d	d	2.4	d	426.7	72.8
1992	875.4	176.3	699.1	121.7	d	0.0	3.2	d	d	d
1993	936.3	218.0	718.3	132.0	d	0.0	3.1	d	d	d
1994	969.2	227.1	742.1	146.1	d	0.0	2.3	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Department of Commerce, Bureau of the Census.

Table 29--Inedible tallow consumption, with inedible by category, United States, 1987/88-94

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1987/88	3,137.8	0.0	3,137.8	502.0	0.0	1,820.3	0.0	69.9	712.6	33.0
1988/89	3,086.7	0.0	3,086.7	374.9	0.0	1,925.4	0.0	70.3	680.0	36.1
1989/90	3,219.0	0.0	3,219.0	398.4	0.0	1,982.9	0.0	109.0	684.0	44.7
1991	2,949.3	0.0	2,949.3	391.5	0.0	1,748.4	0.0	59.6	700.9	48.9
1992	3,050.1	0.0	3,050.1	334.4	0.0	1,954.4	0.0	63.2	659.0	39.1
1993	3,018.2	0.0	3,018.2	299.6	0.0	1,994.7	0.0	71.5	615.1	37.3
1994	3,189.9	0.0	3,189.9	300.8	0.0	2,101.9	0.0	81.8	634.0	71.4

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Department of Commerce, Bureau of the Census.

Table 30--Linseed oil consumption, with inedible by category, United States, 1987/88-94

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1987/88	159.3	0.0	159.3	0.0	85.5	0.0	31.0	d	d	40.5
1988/89	154.9	0.0	154.9	0.0	101.6	0.0	23.1	d	d	28.2
1989/90	110.5	0.0	110.5	0.0	30.3	d	52.5	d	d	23.8
1991	95.8	0.0	95.8	0.0	40.7	0.0	41.6	d	d	12.7
1992	154.4	0.0	154.4	0.0	69.0	0.0	31.3	d	d	d
1993	125.8	0.0	125.8	0.0	66.9	0.0	25.4	d	d	d
1994	124.3	0.0	124.3	0.0	33.0	0.0	50.9	d	d	40.4

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Department of Commerce, Bureau of the Census.

Table 31--Rapeseed oil consumption, with inedible by category, United States, 1989/90-94 1/

Year 2/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 3/	Fatty acids	Other products
					--Million pounds--					
1989/90	d	265.0	d	0.0	d	d	d	d	d	d
1991	d	285.1	d	0.0	0.0	d	0.0	d	d	d
1992	d	360.5	d	0.0	0.0	d	0.0	d	d	d
1993	d	362.5	d	0.0	0.0	0.0	0.0	d	d	d
1994	d	446.3	d	0.0	0.0	0.0	0.0	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Includes both canola and industrial rapeseed. 2/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991.
3/ Includes similar oils.

Source: Department of Commerce, Bureau of the Census.

Table 32--Soybean oil consumption, with inedible by category, United States, 1987/88-94

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1987/88	10,714.5	10,429.1	285.3	2.7	54.1	d	106.1	d	d	72.3
1988/89	9,917.6	9,635.8	281.8	1.5	34.9	d	123.7	d	d	68.2
1989/90	10,808.3	10,536.7	271.6	d	38.2	d	112.4	d	d	52.4
1991	11,267.7	10,966.7	301.0	d	49.2	d	104.7	d	d	40.4
1992	11,471.6	11,168.7	302.8	d	43.5	22.3	94.0	5.9	d	69.8
1993	12,495.6	12,200.9	294.7	d	38.7	23.7	98.1	5.8	d	65.8
1994	12,474.1	12,157.8	316.3	d	47.6	d	119.6	d	d	91.9

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Department of Commerce, Bureau of the Census.

Table 33--Tall oil consumption, with inedible by category, United States, 1987/88-94

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1987/88	1,269.4	0.0	1,269.4	16.8	23.3	0.0	20.9	9.6	1,181.1	17.8
1988/89	1,234.3	0.0	1,234.3	8.3	31.8	0.0	18.0	8.1	1,157.3	10.8
1989/90	1,024.7	0.0	1,024.7	8.4	7.4	0.0	21.7	7.1	969.9	10.2
1991	940.0	0.0	940.0	3.5	5.4	0.0	11.6	4.0	906.5	9.0
1992	883.5	0.0	883.5	d	d	0.0	19.4	7.0	841.8	11.4
1993	891.8	0.0	891.8	d	d	0.0	23.0	6.3	806.9	d
1994	1,362.5	0.0	1,362.5	d	d	0.0	48.4	6.1	1,025.0	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Department of Commerce, Bureau of the Census.

Table 34--Castor oil prices, raw No. 1, tanks, Brazilian, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Cents/pound--						
1989	51.00	51.75	51.90	51.50	51.50	51.50	51.50	51.50	41.20	51.50	51.50	53.75
1990	54.50	53.50	52.60	52.00	51.20	51.00	51.00	51.00	45.00	42.40	39.63	39.63
1991	39.30	36.00	36.75	37.00	37.00	36.50	35.50	35.00	35.00	35.40	35.00	37.50
1992	37.50	37.50	37.50	36.00	34.50	34.50	34.50	34.50	34.00	34.00	34.00	34.00
1993	34.00	32.00	32.00	32.00	37.00	37.00	37.00	37.00	38.50	44.00	44.00	44.00
1994	44.00	41.75	41.00	41.00	46.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
1995	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00				

Source: Chemical Marketing Reporter.

Table 35--Coconut oil prices, crude, tanks, f.o.b. New York, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Cents/pound--						
1989	26.75	27.63	27.90	28.94	29.90	29.56	28.94	27.75	28.63	27.25	26.35	24.81
1990	24.31	23.69	22.10	21.63	21.30	20.31	19.16	18.58	18.26	18.18	20.45	20.13
1991	20.22	20.31	20.50	19.38	19.69	21.69	26.19	25.63	25.63	28.50	31.50	32.38
1992	39.33	36.00	34.57	34.75	33.56	32.13	29.63	27.31	27.88	26.94	27.00	25.50
1993	24.94	24.33	23.65	23.25	24.13	24.95	25.35	25.61	24.44	23.88	25.62	33.06
1994	30.30	30.94	29.56	30.19	29.45	30.25	29.56	30.35	30.63	30.60	34.19	33.69
1995	32.50	32.00	31.13	31.00	30.50	35.00	34.50	35.63				

Source: Chemical Marketing Reporter.

Table 36--Flaxseed, average price received by farmers, United States, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Dollars/bushel--						
1989	8.34	8.70	8.09	7.78	7.54	6.79	5.90	6.49	7.07	7.09	7.15	7.14
1990	7.24	7.69	8.03	8.60	8.23	8.31	7.56	5.86	5.36	5.15	5.16	5.15
1991	5.12	4.80	4.90	4.66	4.33	3.98	3.91	3.69	3.55	3.40	3.31	3.46
1992	3.39	3.43	3.52	3.53	3.61	3.67	3.70	3.71	4.12	4.09	4.10	4.21
1993	4.12	4.47	4.54	4.41	4.35	4.44	4.29	3.80	4.25	4.09	4.05	4.18
1994	4.38	4.61	4.64	4.60	4.43	4.25	4.28	4.52	4.54	4.49	4.51	4.71
1995	4.75	4.94	5.15	5.10	4.93	4.86	5.10	5.14				

Source: National Agricultural Statistical Service, USDA.

Table 37--Industrial rapeseed oil prices, refined, tanks, New York, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Cents/pound--						
1989	70.00	70.00	80.25	80.25	80.25	80.25	80.25	80.25	80.25	64.20	80.25	80.25
1990	81.75	82.25	82.25	82.25	82.25	82.25	82.25	82.25	79.75	77.25	77.25	81.00
1991	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25
1992	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	67.25	62.25	62.25	62.25
1993	62.25	62.25	62.25	62.25	55.88	53.75	53.75	53.75	53.75	53.75	53.75	53.75
1994	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75
1995	53.75	53.75	53.75	53.75	53.15	50.75	50.75	50.75				

Source: Chemical Marketing Reporter.

Table 38--Inedible tallow prices, Chicago, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Cents/pound--						
1989	14.90	16.00	14.86	14.60	14.70	15.10	14.48	13.52	14.13	10.94	14.75	14.25
1990	14.87	14.50	14.47	13.50	13.51	14.01	13.50	10.12	13.50	13.42	14.09	14.50
1991	14.53	12.91	13.63	13.57	12.25	12.36	12.96	14.00	13.50	13.68	13.08	12.50
1992	12.25	12.63	12.68	13.25	13.75	13.98	14.75	15.42	15.25	15.73	16.75	13.52
1993	15.36	14.69	15.24	15.94	15.00	15.11	14.95	14.58	14.54	14.68	14.50	14.94
1994	15.00	15.00	15.22	19.00	15.25	15.63	16.67	18.64	19.50	19.78	20.38	22.48
1995	21.75	18.66	18.00	17.75	17.50	17.89	19.61	19.81				

Source: Grain and Feed Marketing News.

Table 39--Jojoba oil prices, 1 metric ton or more, f.o.b. Arizona, 1989-95 1/

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Dollars/kilogram--						
1989	14.18	14.18	14.18	14.18	14.18	14.18	15.25	15.25	15.25	15.25	15.25	15.25
1990	15.25	20.02	20.02	20.02	20.02	20.02	26.00	26.00	25.00	25.00	24.00	24.00
1991	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	21.00	15.50	15.50	15.50
1992	15.50	15.50	15.50	15.50	15.50	15.50	15.50	13.50	13.50	11.99	11.99	11.99
1993	11.99	11.99	11.99	11.99	12.00	12.00	12.00	12.00	10.02	10.02	10.02	10.02
1994	10.02	10.02	9.01	9.01	9.01	9.01	9.01	9.01	9.01	9.01	9.01	8.48
1995	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48				

1/ Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 40--Linseed oil prices, tanks, Minneapolis, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Cents/pound--						
1989	41.00	41.00	41.40	42.00	42.00	39.75	39.00	39.00	39.50	40.00	40.00	39.50
1990	40.00	40.00	41.60	42.00	42.00	43.00	44.00	40.40	39.75	36.80	36.00	36.00
1991	36.00	36.00	36.00	36.00	36.50	36.00	36.00	36.00	36.00	30.00	30.00	30.00
1992	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	32.00	32.00	32.00	32.00
1993	32.00	32.00	32.00	32.00	32.00	28.50	32.00	32.00	32.00	32.00	32.00	32.00
1994	32.00	32.00	32.00	32.00	32.00	32.00	30.31	32.00	32.00	33.50	35.00	35.00
1995	35.00	35.00	35.00	35.00	35.00	35.00	35.00					

Source: Grain and Feed Marketing News.

Table 41--Linseed meal prices, bulk, 34 percent protein, Minneapolis, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Dollars/ton--						
1989	164.00	151.25	150.00	155.00	156.00	162.50	158.75	161.00	145.00	129.00	126.25	128.75
1990	132.50	124.50	126.25	133.75	143.00	142.50	136.00	126.25	116.25	133.00	143.75	133.50
1991	131.00	131.25	120.00	121.00	126.25	134.25	133.00	131.25	116.25	128.00	113.75	127.80
1992	122.00	124.00	115.00	117.50	120.00	125.00	123.50	126.25	131.00	141.25	152.50	137.40
1993	136.70	142.50	135.40	125.50	125.00	123.20	133.75	150.00	148.75	147.50	161.80	140.00
1994	140.00	130.00	126.00	125.00	125.00	111.40	114.90	111.60	N.A.	122.50	110.00	95.60
1995	82.40	85.25	90.00	94.40	85.00	85.00	92.50					

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 42--Palm kernel oil prices, bulk, c.i.f. U.S. ports, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Cents/pound--						
1989	23.63	23.81	23.94	23.59	25.09	23.91	22.50	21.38	22.16	22.19	21.28	19.75
1990	20.17	18.58	18.00	16.50	17.44	16.17	15.42	14.94	14.75	16.00	17.75	17.75
1991	18.94	17.92	17.25	16.08	16.38	17.08	24.63	24.67	20.92	24.35	25.00	29.38
1992	34.50	35.00	31.58	34.00	31.50	30.08	27.42	25.42	26.88	26.50	26.42	24.50
1993	23.00	23.00	21.67	20.67	32.08	33.33	31.33	31.92	21.00	20.67	22.50	30.94
1994	29.88	27.58	26.75	29.56	32.08	33.33	31.25	31.92	34.75	36.33	37.33	39.13
1995	37.08	34.33	34.70	31.75	31.00	34.50	35.25	34.31				

Source: Chemical Marketing Reporter.

Table 43--Soybean oil prices, crude, tanks, f.o.b. Decatur, 1989-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						--Cents/pound--						
1989	21.13	21.21	22.11	21.97	22.23	20.75	19.66	18.08	18.77	19.02	19.57	19.11
1990	19.28	20.27	22.80	23.35	24.72	25.03	24.69	25.05	24.45	22.59	21.05	21.55
1991	21.56	21.66	22.21	21.50	20.23	19.65	19.05	20.23	20.46	19.57	18.78	18.99
1992	18.77	18.88	19.74	19.00	20.15	20.71	18.82	17.87	18.28	18.36	20.10	20.52
1993	21.23	20.72	21.00	21.24	21.15	21.30	24.13	23.46	20.93	23.61	22.98	24.22
1994	29.91	28.85	29.03	27.94	29.48	29.43	27.20	25.02	24.87	24.73	24.75	24.75
1995	29.04	28.15	28.33	26.30	26.00	26.78	27.60	26.56				

Source: The Wall Street Journal.

Table 44--Cedarwood oil prices, drums or cans, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
Chinese												
1992	N.A.	1.55	1.55	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1993	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1994	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1995	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70			
Texas												
1992	N.A.	3.20	3.20	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
1993	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
1994	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.70
1995	3.70	3.70	3.70	3.70	3.70	3.70	3.70	4.15	4.15			
Virginia												
1992	N.A.	5.25	5.25	5.35	5.35	5.35	5.35	5.35	5.50	5.50	5.50	5.50
1993	5.80	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1994	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1995	6.50	6.70	6.70	6.70	6.70	6.90	6.90	6.90	6.90			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 45--Citronella oil prices, drums, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
Java												
1992	N.A.	1.95	1.95	2.38	2.38	2.38	2.38	2.38	2.53	2.53	2.53	2.53
1993	2.53	2.53	2.53	2.53	2.53	3.10	3.10	3.10	3.10	3.60	3.80	4.00
1994	4.00	4.30	4.30	4.15	4.15	4.15	4.15	4.75	4.75	5.00	5.50	6.00
1995	6.00	7.90	8.43	8.43	8.43	8.60	8.60	N.A.	N.A.			
China												
1992	N.A.	1.90	1.90	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
1993	2.20	2.25	2.35	2.35	2.35	3.13	3.13	3.13	3.13	3.25	3.50	4.00
1994	4.00	4.20	4.20	4.05	4.05	4.05	4.05	4.40	4.40	5.00	5.40	6.10
1995	7.00	7.90	8.35	8.35	8.35	8.60	8.60	7.90	6.80			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 46--Eucalyptus oil prices, Chinese, 80 percent, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
1992	N.A.	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
1993	2.88	2.88	2.88	2.88	2.88	2.63	2.63	2.63	2.63	2.63	2.63	2.63
1994	2.63	2.63	2.63	1.90	1.90	1.90	1.90	2.00	2.00	2.00	2.00	2.15
1995	2.38	2.50	2.50	2.80	3.00	3.20	3.20	3.20	2.90			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 47--Grapefruit oil prices, drums, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
Florida												
1992	N.A.	5.00	5.00	5.25	5.25	5.25	5.25	5.50	4.95	4.95	4.95	4.95
1993	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1994	6.00	6.00	6.00	6.75	6.75	6.75	7.50	8.25	8.25	8.25	8.25	8.25
1995	8.25	8.25	8.25	11.25	11.25	11.25	11.25	11.25	15.75			
Israeli												
1992	N.A.	4.25	4.25	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
1993	N.A.	N.A.	N.A.	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63
1994	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63
1995	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 48--Lemon oil prices, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
Argentina												
1992	N.A.	9.50	9.50	9.50	9.50	9.50	9.50	9.50	10.25	10.25	10.25	10.25
1993	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
1994	10.25	11.00	11.00	11.00	11.00	11.00	11.50	11.50	11.50	11.50	11.50	12.25
1995	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.65	12.65			
California, U.S. Pharmacopeia, drums												
1992	N.A.	8.93	8.93	8.93	8.93	8.93	10.50	10.50	10.50	10.50	10.50	10.50
1993	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	9.50
1994	9.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50
1995	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50			
Italian												
1992	N.A.	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1993	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1994	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1995	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 49--Lime oil prices, distilled, Mexican, drums, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
1992	N.A.	9.75	9.75	9.75	9.75	9.75	9.75	9.75	10.25	10.25	10.25	10.25
1993	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
1994	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.75	10.75	10.75	10.75	10.75
1995	10.75	10.75	10.75	10.75	10.75	10.75	12.00	13.50	13.50			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 50--d-Limonene prices, drums, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
1992	N.A.	0.70	0.70	0.73	0.73	0.73	0.73	0.78	0.78	0.78	0.78	0.78
1993	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
1994	0.78	0.78	0.78	0.83	0.83	0.83	0.83	0.83	0.83	1.05	2.00	2.00
1995	2.00	2.00	2.35	2.35	3.00	3.00	3.00	2.50	2.50			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 51--Menthol prices, natural, Chinese, drums, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
1992	N.A.	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58
1993	6.35	5.68	5.68	5.10	5.10	5.10	5.10	5.10	5.10	5.00	5.00	5.00
1994	5.00	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	9.50	11.50	12.00
1995	12.00	12.50	11.00	9.75	9.75	9.00	9.00	9.00	9.80			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 52--Orange oil prices, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
California, distilled, cans, f.o.b. plant												
1992	N.A.	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
1993	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
1994	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	2.00	2.00
1995	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50			
Florida, drums 1/												
1992	N.A.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
1993	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
1994	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.10	2.00	2.00
1995	2.00	2.25	2.50	2.75	2.75	2.75	2.75	2.75	2.75			
Brazilian 2/												
1992	N.A.	0.80	0.80	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1993	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1994	0.75	0.75	0.75	0.78	0.78	0.78	0.78	0.78	0.78	1.10	2.00	2.00
1995	2.00	2.40	2.40	2.55	2.70	2.70	2.70	2.43	2.63			

N.A. = Not available.

1/ Florida, midseason, drums beginning in February 1994. 2/ Pera Brazil, drums, f.o.b. plant beginning in February 1994.

Source: Chemical Marketing Reporter.

Table 53--Peppermint oil prices, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
Midwest U.S.												
1992	N.A.	18.00	14.50	14.50	14.50	14.50	14.50	14.50	13.35	13.35	13.35	13.35
1993	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.50	13.50	13.50
1994	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1995	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50			
Yakima U.S.												
1992	N.A.	15.00	13.50	13.50	13.50	13.50	13.50	13.50	12.30	12.30	12.30	12.30
1993	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	15.00	15.00	15.00
1994	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
1995	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00			
Synthetic, drums, f.o.b. works												
1992	N.A.	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
1993	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	10.00	10.00	10.00	10.00
1994	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1995	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00			
Chinese												
1992	N.A.	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.38	9.88
1993	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88
1994	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88
1995	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88	9.88			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 54--Spearmint oil prices, 1992-95

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Dollars per pound						
Far West, native												
1992	N.A.	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
1993	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	11.00	11.00	11.00
1994	11.00	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
1995	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50			
Far West, Scotch												
1992	N.A.	20.00	16.00	15.00	15.00	15.00	15.00	13.00	14.40	14.40	14.40	14.40
1993	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	12.50	12.50	12.50
1994	12.50	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
1995	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00			
Chinese, 80 percent												
1992	N.A.	27.50	27.50	26.40	26.40	26.40	26.40	26.40	26.40	26.40	26.40	26.40
1993	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
1994	7.50	7.50	7.50	7.50	7.50	5.75	5.75	5.75	5.75	5.75	5.50	6.00
1995	6.00	6.70	6.70	6.70	7.00	7.00	7.00	7.50	8.50			

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 55--Selected prices for biobased chemicals and derivatives 1/

Item	Unit	Average annual price 2/ 1989	1990	1991	1992	1993	1994	1995
Starches, sugars, and gums								
Arabic gum, National Formulary, powdered, barrels	Dollars per pound	1.85	1.85	1.85	2.67	3.44	4.00	4.00
Denatured alcohol, ethyl (ethanol), CD18, CD19, tanks, delivered east	Dollars per gallon	2.09	2.11	2.08	2.02	2.02	2.26	2.41
Dextrin, corn, canary dark, paper bags, carload, works	Cents per pound	31.01	32.00	32.00	32.00	32.00	32.00	32.00
Dextrose, hydrated, commercial, bags, carload, delivered New York	Cents per pound	25.29	25.50	25.50	25.50	25.50	25.50	21.86
Furfural, tanks, f.o.b. plant	Cents per pound	75.00	77.33	79.00	79.00	79.00	79.00	79.00
Guar gum, industrial, high viscosity, bags, carload, f.o.b. shipping point	Cents per pound	35.00	35.00	35.00	35.00	35.00	39.92	45.00
Karaya gum, No. 1, powdered, drums	Dollars per pound	3.50	3.31	3.25	3.25	3.25	3.25	3.25
Locust bean gum, powdered, bags	Dollars per pound	4.75	4.75	4.75	4.75	4.63	4.71	7.00
Pectin, high methoxyl	Dollars per pound	3.30	3.30	3.30	4.03	4.75	4.75	4.75
Sorbitol, U.S. Pharmacopeia, regular, 70-percent aqueous, drums, carload, f.o.b. shipping point	Cents per pound	39.58	40.17	33.29	33.00	33.00	33.00	33.00
Sucrose acetate isobutyrate, 90-percent, drums, truckload, delivered	Dollars per pound	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Sucrose octa-acetate, denaturing grade, 100-pound drums, f.o.b. works	Dollars per kilogram	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Tragacanth gum, No. 1, ribbons, 100-pound drums	Dollars per pound	36.00	36.00	36.00	36.00	36.83	41.00	41.00
Xanthan gum, food grade, 100-pound drums, f.o.b. works	Dollars per pound	5.65	5.65	5.65	5.65	5.74	6.20	6.20
Fats, oils, and waxes								
Beeswax, refined, bleached, white bricks, 100-pound cartons	Dollars per pound	3.10	3.10	3.10	3.12	3.35	3.33	3.32
Butyl stearate, technical, tanks, f.o.b. works	Cents per pound	55.00	55.00	55.00	55.00	54.75	54.00	54.00
Capryl alcohol, secondary, 98-percent, tanks, f.o.b. works	Cents per pound	42.00	43.00	48.00	48.00	48.00	66.33	68.00
Caprylic acid, commercial, pure, tanks	Cents per pound	72.83	78.33	83.00	90.92	102.00	102.00	102.00
Carnauba wax, Parnahyba, No. 1, yellow, bags, ton lots	Dollars per pound	2.50	2.50	2.88	3.23	3.50	3.50	4.46
Glycerine, natural, refined, U.S. Pharmacopeia, 99.7-percent, tanks, delivered	Cents per pound	79.00	75.92	64.00	56.63	64.08	100.75	110.14
Lecithin, unbleached, bulk, less carload, works	Cents per pound	37.00	35.00	29.00	28.00	25.75	25.00	25.00
Magnesium lauryl sulfate, tanks, f.o.b.	Cents per pound	36.00	43.00	43.00	43.00	47.75	57.25	57.25
Magnesium stearate, bulk	Dollars per pound	1.16	1.16	1.16	1.16	1 20	1.20	1.20
Menhaden oil, bulk, Gulf ports	Cents per pound	11.33	10.94	13.13	15.83	16.54	16.50	16.50
Myristic acid, commercial, pure, bags, truckload	Dollars per pound	0.88	0.79	0.67	1.10	1.25	1.17	1.15
Oleic acid, double distilled (white), tanks	Cents per pound	54.00	54.00	54.00	54.00	60.42	61.00	61.00
Sebacic acid, chemically pure, bags, carload, works	Dollars per pound	1.98	2.05	2.05	2.05	2.05	2.05	2.05
Sodium lauryl sulfate, 30-percent, drums, truckload, f.o.b. works	Cents per pound	38.33	43.00	43.00	43.00	47.75	57.25	57.25
Tallow fatty acids, technical, tanks, delivered	Cents per pound	29.00	29.00	24.88	23.50	23.50	23.50	23.50
Animal products								
Casein, acid precipitated, ground, 30-mesh, edible, imported, truckload, c.i.f.	Dollars per pound	2.50	2.50	2.50	2.52	2.55	2.55	2.55
Gelatin, edible, 100 AOAC test, drums, less truckload, delivered	Dollars per pound	1.50	1.50	1.54	1.68	1.70	1.70	1.70
Glue, bone, extracted, green, 85 jellygrams, bags, carload	Cents per pound	95.00	95.00	95.00	94.00	89.00	89.00	89.00
Lanolin, anhydrous, pharmaceutical, 400-pound drums, works	Dollars per pound	0.90	1.01	1.00	1.25	1.25	1.25	1.25
Forest products								
a-Pinene prices, technical grade	Cents per pound	33.00	43.00	43.00	43.00	52.00	60.00	60.00
b-Pinene 3/	Cents per pound	35.00	55.00	55.00	55.00	3/	114.00	114.00
Cellulose acetate, powdered, bags, truckload, delivered east	Dollars per pound	1.50	1.58	1.62	1.94	2.12	2.12	2.12
Tall oil, crude, Southeast, tanks, freight equaled	Dollars per ton	140.00	135.42	159.17	150.83	119.17	121.25	154.29
Turpentine prices, crude sulfate, tanks, f.o.b. Southeast	Dollars per gallon	2.05	1.75	1.36	0.88	0.68	0.50	0.53

See next page for footnotes and definitions.

1/ Spot and/or list prices from the *Chemical Marketing Reporter* for selected chemicals and related materials on a New York or other indicated basis. These prices do not represent bid, asked, or actual transaction prices. Variations from these prices may occur for differences in quantity, quality, and location. 2/ Some prices are from the low end of range. 3/ Price changed from technical grade to 97 percent perfume and flavor grade in October 1993.

Chemical definitions:

Arabic gum is a dried, water-soluble exudate from the stems of *Acacia senegal* and related species that is used in pharmaceuticals, adhesives, inks, textile printing, cosmetics, and confectionery and food products.

Denatured ethyl alcohol is made by yeast fermentation of carbohydrates or by hydrolysis of ethylene for solvents, cosmetics, and as an oxygenated gasoline additive.

Dextrin is obtained by heating acidified dry starch for adhesives and paper products.

Dextrose is obtained from cornstarch hydrolysis for use in foods and as a fermentation substrate.

Furfural is obtained by steam distillation of acidified plant materials for polymers and foundry binders.

Guar gum is a water-dispersible hydrocolloid from the seeds of the guar plant that is used in foods and industrial applications such as oil-well fracturing fluids.

Karaya gum is a hydrophilic polysaccharide from Indian trees of the genus *Sterculia* for use in pharmaceuticals, textile coatings, ice cream and other food products, and adhesives.

Locust bean gum is a polysaccharide plant mucilage from seeds of *Ceratonia siliqua* used in cosmetics, textiles sizings and finishes, and drilling fluids, and in foods as a stabilizer, thickener, and emulsifier.

Pectin is obtained from citrus fruit rinds for use in jellies, foods, cosmetics, and drugs.

Sorbitol is obtained by hydrogenation of glucose for foods, cosmetics, and polyester polymers.

Sucrose acetate isobutyrate is made by controlled esterification of sucrose with acetic and isobutyric anhydrides for hot-melt coating formulations and extrudable plastics.

Sucrose octa-acetate is used as a plasticizer for cellulose esters and plastics, and in adhesive and coating compounds.

Tragacanth gum is polysaccharides from *Astragalus* bushes for use in pharmaceutical emulsions, adhesives, leather dressing, textile printing and sizing, dyes, and printing inks.

Xanthan gum is a synthetic, water-soluble polymer made by fermentation of carbohydrates for use in drilling fluids, ore floatation, foods, and pharmaceuticals.

Beeswax is a byproduct of honey production used for cosmetics and candles.

Butyl stearate is obtained by alcoholysis of stearin or esterification of stearic acid with butanol for use in polishes, special lubricants, and coatings and as a plasticizer and emollient in cosmetics and pharmaceuticals.

Capryl alcohol is obtained by distilling sodium ricinoleate, a castor oil derivative, with an excess of sodium hydroxide for solvents, plasticizers, wetting agents, and petroleum additives.

Caprylic acid is a fatty acid obtained from coconut oil for use in synthesizing dyes, drugs, perfumes, antiseptics, and fungicides.

Carnauba wax is a hard commercial wax obtained from leaves of *Copernica cerifera* for shoe, furniture, and floor polishes; leather finishes; varnishes; electric-insulating compounds; and carbon paper.

Glycerine is a byproduct of splitting or saponification of fats and oils, or made by petrochemical synthesis for cosmetics, food, drugs, and polyurethane polymers.

Lecithin is a byproduct of soy oil extraction used as an emulsifying agent and antioxidant in foods.

Magnesium lauryl sulfate is a surfactant derived from fatty acids for use in plastics, plasticizers, textile applications, and consumer end-product manufacturing.

Magnesium stearate is a surfactant made from tropical oil fatty acids and inorganic materials for use in lubricant, adhesive, and detergent manufacturing.

Menhaden oil is obtained from menhaden fish for soaps, rubber compounding, printing inks, animal feed, and leather-dressing lubricants.

Myristic acid is obtained by fractional distillation of coconut and other vegetable oils for soaps, cosmetics, and synthesis of esters for flavors and perfumes.

Oleic acid is obtained by fractional crystallization from mixed fatty acids for candles, soaps, and synthesis of other surfactants.

Sebacic acid is made by high-temperature cleavage of castor oil for use as an intermediate chemical in the manufacture of polymers and plasticizers.

Sodium lauryl sulfate is synthesized from fatty acids for use in toothpaste and as a food additive and wetting agent for textiles.

Tallow fatty acids are made from splitting tallow for direct use as lubricants or in greases, and for separation into pure fatty acids.

Casein is a coagulated and dried milk protein for adhesives and plastics.

Gelatin is water extracted from bones and hides for photographic emulsions and food.

Glue (bone) is obtained by steam treatment and water extraction of bones for glue and mineral flotation processes.

Lanolin is extracted from wool for cosmetics, leather dressing, and lubricants.

a-Pinene and *b-Pinene* are chemical intermediates fractionated from turpentine that are converted to pine oil (a-Pinene), terpene resins (b-Pinene), and specialty chemicals.

Cellulose acetate is made by reacting cellulose from wood with acetic acid for rayon textiles and cigarette filters.

Tall oil (crude) is a byproduct of paper production (chemical pulping) for refining into rosin and fatty acids.

Turpentine (crude sulfate) is obtained by steam distillation of pine gum recovered from pulping softwoods (for paper production), which is used for a- and b-pinene.

Table 56--U.S. imports of nonwood fibers, yarns, twine, and cordage, 1989-94

Item	Unit	1989	1990	1991	1992	1993	1994
Flax, raw or processed but not spun	Metric tons	72,222	67,659	55,046	48,166	47,030	55,059
Jute, raw or processed but not spun	Metric tons	6,831	3,931	5,468	6,246	7,326	7,026
Flax yarn	Kilograms	528,770	587,553	413,301	690,248	888,656	1,113,918
Jute yarn	Kilograms	7,893,451	5,757,241	7,489,781	5,380,531	5,046,250	4,312,393
Abaca twine and cordage	Kilograms	6,321,518	7,571,631	6,111,529	5,623,279	6,930,999	7,652,898
Jute twine and cordage	Kilograms	1,772,656	3,321,647	1,998,699	6,623,013	7,606,930	15,403,623
Sisal twine and cordage	Kilograms	86,202,330	87,114,936	76,371,329	73,056,843	71,595,465	78,704,800

Source: Department of Commerce, Bureau of the Census.

Table 57--U.S. exports of nonwood fibers, yarns, twine, and cordage, 1989-94

Item	Unit	1989	1990	1991	1992	1993	1994
Flax, raw or processed but not spun	Metric tons	150	160	559	3,687	121	92
Jute, raw or processed but not spun	Metric tons	5,872	3,539	3,135	1,534	1,202	2,353
Flax yarn	Kilograms	31,645	219,806	123,132	209,218	363,084	112,330
Jute yarn	Kilograms	801,488	626,861	604,414	591,864	575,383	236,225
Jute twine and cordage	Kilograms	356,962	157,922	200,323	305,873	297,794	462,136
Sisal twine and cordage	Kilograms	264,202	1,231,926	1,250,597	1,366,504	1,150,473	519,285

Source: Department of Commerce, Bureau of the Census.

Table 58--U.S. imports of selected vegetable oils, 1989-94

Item	Unit	1989	1990	1991	1992	1993	1994
Castor oil, crude and refined	Metric tons	37,835	30,969	34,523	34,018	42,214	44,094
Coconut oil, crude and refined	Metric tons	391,903	452,227	390,994	501,466	443,496	441,332
Linseed oil, crude and refined	Metric tons	3	8	94	351	159	426
Jojoba oil and its fractions	Metric tons	216	182	384	235	142	198
Tung oil and its fractions	Metric tons	6,472	4,045	5,645	4,995	4,272	5,404

Source: Department of Commerce, Bureau of the Census.

Table 59--U.S. exports of selected vegetable oils, 1989-94

Item	Unit	1989	1990	1991	1992	1993	1994
Coconut oil, crude and refined	Metric tons	20,431	18,218	21,131	9,448	6,364	8,494
Linseed oil, crude and refined	Metric tons	6,767	3,026	4,469	3,940	3,804	5,402
Jojoba oil and its fractions	Metric tons	213	279	327	209	351	287
Tung oil and its fractions	Metric tons	217	312	500	329	297	176

Source: Department of Commerce, Bureau of the Census.

Table 60--U.S. imports of pulp and paper products, 1989-94

Item	Unit	1989	1990	1991	1992	1993	1994
Chemical woodpulp	Metric tons	4,046,477	3,924,446	4,085,883	4,145,682	4,435,134	4,629,028
Semichemical woodpulp	Metric tons	153,811	172,213	163,516	175,290	245,046	226,845
Mechanical woodpulp	Metric tons	173,319	141,186	126,570	107,983	145,804	199,878
Cotton linters pulp	Metric tons	503	110	1	20	10	20
Other cellulosic fiber pulps	Thou. metric tons	9,706	12,624	10,735	9,360	7,377	15,791
Newsprint	Metric tons	7,953,643	7,529,308	6,794,898	6,658,426	7,061,513	7,149,976
Writing paper with less than 10 percent mechanical pulp	Kilograms	270,490,245	303,174,702	215,221,877	248,618,324	275,800,767	190,676,102
Straw paper and paperboard	Kilograms	50,000	8,415	833	678	9,756	528,865
Corrugated paper and paperboard	Kilograms	5,219,325	12,621,535	4,067,556	4,551,194	2,724,891	19,236,125

Source: Department of Commerce, Bureau of the Census.

Table 61--U.S. exports of pulp and paper products, 1989-94

Item	Unit	1989	1990	1991	1992	1993	1994
Chemical woodpulp	Metric tons	4,831,039	4,608,672	5,003,677	5,734,372	5,213,541	5,388,110
Semichemical woodpulp	Metric tons	32,414	11,019	15,291	19,578	24,885	24,450
Mechanical woodpulp	Metric tons	30,904	28,536	30,313	71,180	69,094	67,342
Cotton linters pulp	Metric tons	69,112	60,832	67,591	74,717	70,140	84,611
Other cellulosic fiber pulps	Metric tons	41,606	62,212	30,854	30,477	42,947	12,049
Writing paper with less than 10 percent mechanical pulp	Kilograms	24,510,287	21,710,457	48,753,346	74,413,780	69,953,501	116,852,248
Straw paper and paperboard	Kilograms	188,716	246,957	256,011	284,247	98,652	557,401
Corrugated paper and paperboard	Kilograms	41,572,999	67,643,829	55,948,853	48,058,868	43,613,552	41,433,989

Source: Department of Commerce, Bureau of the Census.

United States
Department of Agriculture
1301 New York Avenue, NW
Washington, DC 20005-4789

It's Easy To Order Another Copy!

Just dial 1-800-999-6779. Toll free in the United States and Canada.
Other areas, call 1-703-834-0125.

Ask for *Industrial Uses of Agricultural Materials (IUS-5).*

The cost is $15.00 per copy. For non-U.S. addresses (including Canada), add 25 percent. Charge your purchase to your VISA or MasterCard. Or send a check or purchase order (made payable to ERS/NASS) to:

ERS-NASS
341 Victory Drive
Herndon, VA 22070

Watch for the next issue of *Industrial Uses of Agricultural Materials* in late September 1996!